INTERNATIONAL COURT OF JUSTICE

DISPUTE CONCERNING

CONSTRUCTION OF A ROAD IN COSTA RICA ALONG THE SAN JUAN RIVER

(NICARAGUA V. COSTA RICA)

WHICH HAS BEEN JOINED WITH THE CASE CONCERNING

CERTAIN ACTIVITIES CARRIED OUT BY NICARAGUA IN THE BORDER AREA

(COSTA RICA V. NICARAGUA)

REPLY

OF THE REPUBLIC OF NICARAGUA

REPUBLICA DE NICARAGUA
AMERICA CENTRAL

VOLUME II

(ANNEXES 1 TO 30)

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LIST OF ANNEXES
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CENTRAL AMERICAN DOCUMENTS

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MEDIA REPORTS

ANNEX 1

Dr. G. Mathias Kondolf, "Erosion and Sediment Delivery to the Rio San Juan from Route 1856," July 2014

Erosion and Sediment Delivery to the Río San Juan from Route 1856
G. Mathias Kondolf, PhD[1]
July 2014

1. Introduction

The purpose of this report is to review the impacts of Rte 1856 in light of studies reported in the scientific literature and observations of eroding sites along Rte 1856, to identify gaps in Rte 1856 and safety dangers posed by these and within completed sections of the road, and to critique the arguments put forth by Cost Rica's consultants and its agency staff to defend the road.

Rte 1856 is failed or incomplete in multiple places (Sections 2). Erosion and stream crossing failure are worsening, not improving (Section 3). These problems are not "typical," as Costa Rica's experts claim, but rather reflect widespread violations of well-established standards for the construction of roads of this type (Section 4). In its current state, Rte 1856 is unsafe to use, and would pose a significant threat to the Río San Juan if any hazardous materials were transported on it (Section 5). These failing portions of the road are large point sources of sediment to the Río San Juan. Attempts at erosion control have been limited to the upper 15 km of Rte 1856 along the Río San Juan, and where not actually counterproductive, are insufficient to meaningfully control erosion and failure on severely eroding slopes and stream crossings (Section 6).

The report then identifies key flaws in the argument advanced by Costa Rican consultants and agency staff regarding the impacts of Rte 1856 on the Río San Juan. It first explains that Costa Rica's experts underestimate the amount of sediment the Road is contributing to the Río San Juan, and provides an updated estimate of that contribution (Section 7). It then explains that this contribution is not natural or beneficial, and that road-impacted areas in the river are already exhibiting impacts to water quality and aquatic life (Section 8). Next, the report highlights problems in Costa Rica's comparison of sediment contributions from Rte 1856 to claimed total load figures (Section 9), which Costa Rica wrongly characterizes as being "naturally" high (Section 10). The report explains that the sediment contributions from the Road are causing morphological changes in the river, both in the form of deltas along the Costa Rican bank, and because the Lower San Juan is already overloaded with sediment from Costa Rica's other high contributions, such that additional inputs are likely to aggrade and accrete (Section 11). The report reiterates the previously expressed concern that Rte 1856 is not fit to face a serious storm, hurricane, or earthquake, any of which could be expected to dramatically increase the amount of sediment being delivered from the road to the river (Section 12). Finally, the report offers some conclusions (Section 13).

[1] In preparing this report, I have received support from Pacific Watershed Associates, including Danny Hagans and Bill Weaver, who were co-authors on my 2012 Report, and who have now authored their own report, *Evaluation of Erosion, Environmental Impacts and Road Repair Efforts at Selected Sites along Juan Rafael Mora Route 1856 in Costa Rica, Adjacent the Río San Juan, Nicaragua* (July 2014).

2. Rte 1856 is Not Complete.

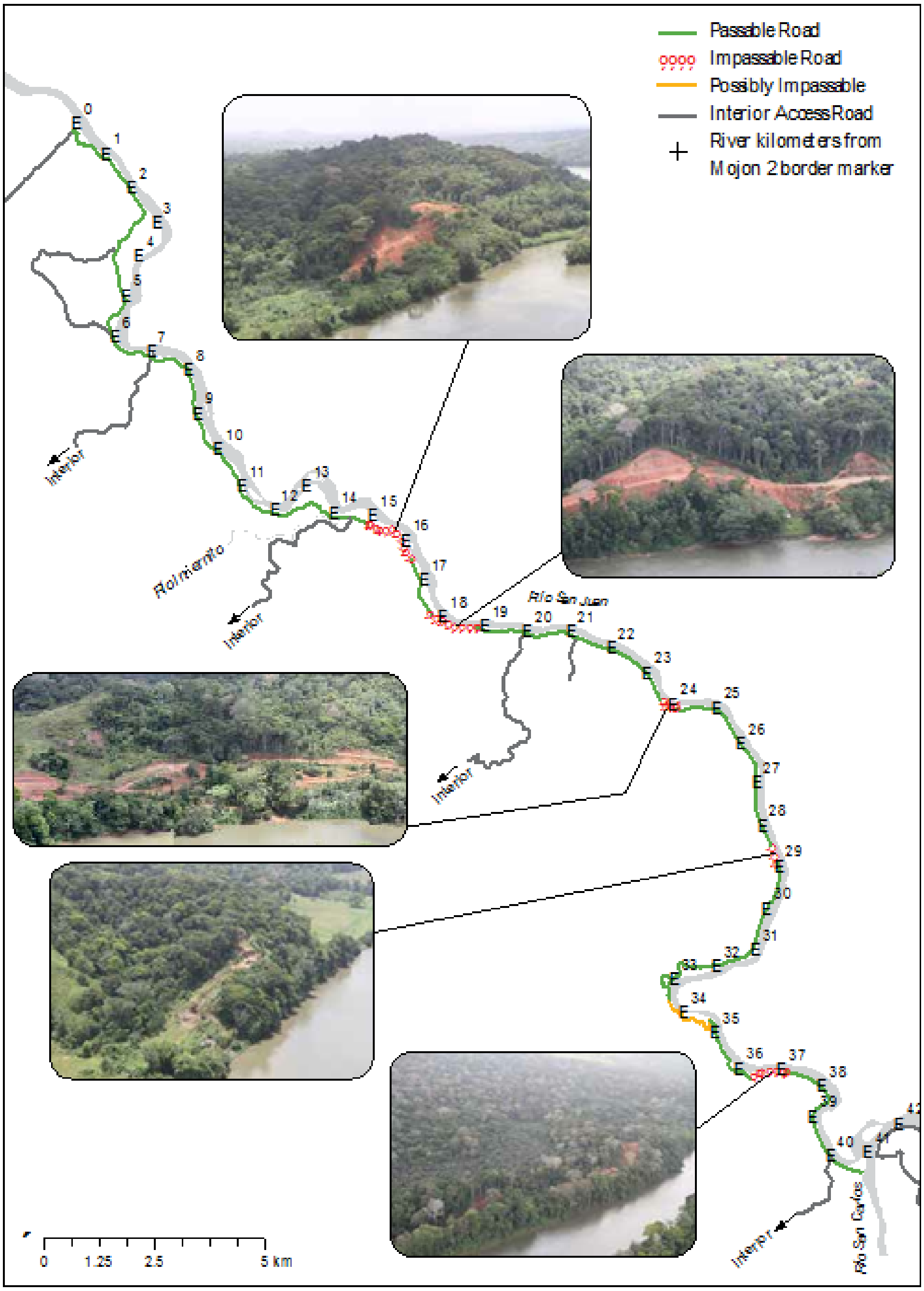
The documents submitted by Costa Rica could give the impression that the road is completed and there are some minor erosion problems, which are being fixed. This is not true. In reality, Rte 1856 is not complete, and it cannot be driven continuously from Mojon II to Boca San Carlos. There have been significant failures on some of the steep slopes across which the road was attempted. At least 3 km of the uppermost 30 km of the road has failed or the attempts to build it appear to have been abandoned due to failures.

The fact that much of the road has not been built or has failed is visible in aerial imagery, and is acknowledged in passing by Professor Colin Thorne in his report, who stated that he "…inspected the entire length of the Road along the Río San Juan (except for those stretches that either do not exist or are inaccessible by four wheel drive vehicle)" (p.19). However, elsewhere Thorne refers to the "the first 41.6 km of the Road alongside the River" (Thorne 2013b, p.73, Vol. II:p.219). While many reports refer to the road length as 108 km total along the river and 41.6 km upstream of Boca San Carlos, in reality the road itself is *not* 41.6 km long in the upper stretch because it has not been completed in sections (totaling over 3 km of the uppermost 30 km) due to failures in attempts to build the road across steep terrain and to cross streams. This reach of *river* is 41.6 km long, but the road is incomplete, and thus its constructed length is less, and its usable length is less still.

There are at least five significant gaps in Rte 1856 between Mojon II and Boca San Carlos (Figure 1), where the road is impassable because of failures, or construction attempts were abandoned due to failures on adjacent sections. In addition, a section around Rkm[2] 34-35 is likely impassable, but would need closer inspection to determine with confidence.

[2] Rkm refers to river km downstream of Mojon II, the point downstream from which the south bank of the Rio San Juan is also the border with Costa Rica.

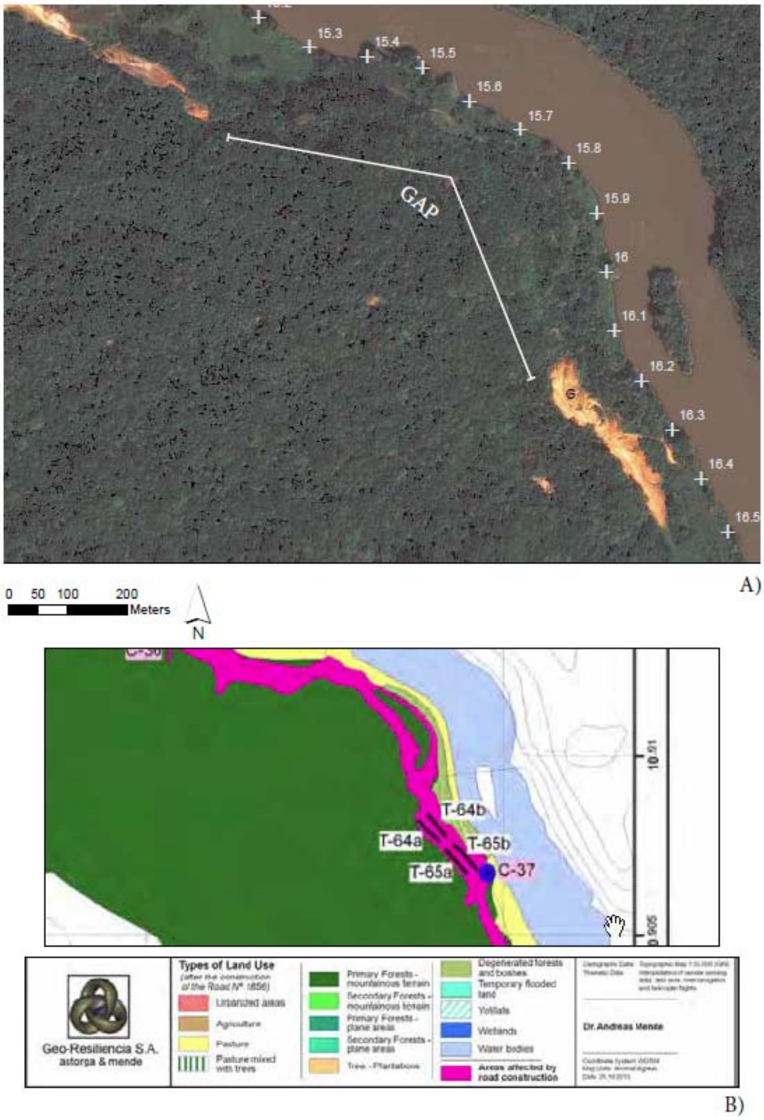
Figure 1. Map of passable and impassable portions of Rte 1856 along the Río San Juan from Mojon 2 to Boca San Carlos.



The Gap Below Rio Infiernito

Attempts to build the road were completely abandoned from Rkm 15.3-16.1 (i.e., 15.3-16.1 km downstream of Mojon II), as visible on the high-resolution 2013 imagery in Figure 2. It appears that trees were cut, but the land was not altered with bulldozers before the attempt to build the road was abandoned. Vegetation has resprouted from the area cut. The maps of Mende and Astorga's (2013) "slope inventory" do not show a gap in the red footprint of the road "affected" area here (between "slopes" T-61 and T-64b), but show the red footprint of disturbance continuing through the gap. Their mapping of this as disturbed may reflect the initial clearing before the construction attempt was abandoned, but clearly this is a gap in the attempted road construction (Figure 2).

Figure 2, The gap in Rte 1856 from Rkm 15.3 – 16.1. A) Detail from Dec 2013 high-resolution satellite image showing the gap. B) Detail from the "slope inventory" map of Mende and Astorga (2013), Annex 6, covering the same area.



Las Crucitas

The section from Rkm 17.8 to 18.3 is a spectacularly eroding section of Rte 1856, with multiple failed cutslopes, fillslopes, and stream crossings. There are three massive stream crossings flanked by four large cuts in steep hillslopes and attendant fillslopes, all undergoing active erosion. This 1.5-km section is a gap in Rte 1856, as stream crossings have failed, been poorly repaired (as shown in Section 3), and will inevitably fail again. The road here may be navigable by dirt bike, donkey, or on foot, but not by normal road vehicles. The failed stream crossings in this section are designated as Sites 9.4, 9.5, and 9.6 in the Inventory of Severely Eroding Sites (Appendix A), described in more detail below in Section 3, and they constitute an impassable section of road, as is clear from December 2013 satellite imagery (Figure 3).

Figure 3. Satellite image from December 2013 at Las Crucitas.

La Chorrera

In the section from Rkm 23.6 to 24.4 (known locally as "La Chorrera"), contractors made multiple failed attempts to cross Caño La Chorrera: four different attempted routes appear as eroding scars on the hillslope (Figure 4). The most recently used crossing was constructed by filling across what used to be an embayment off the main river, a pool under a canopy of trees, which formerly provided off-channel habitat for fish but is now filled by an earthen stream crossing (Figure 5).

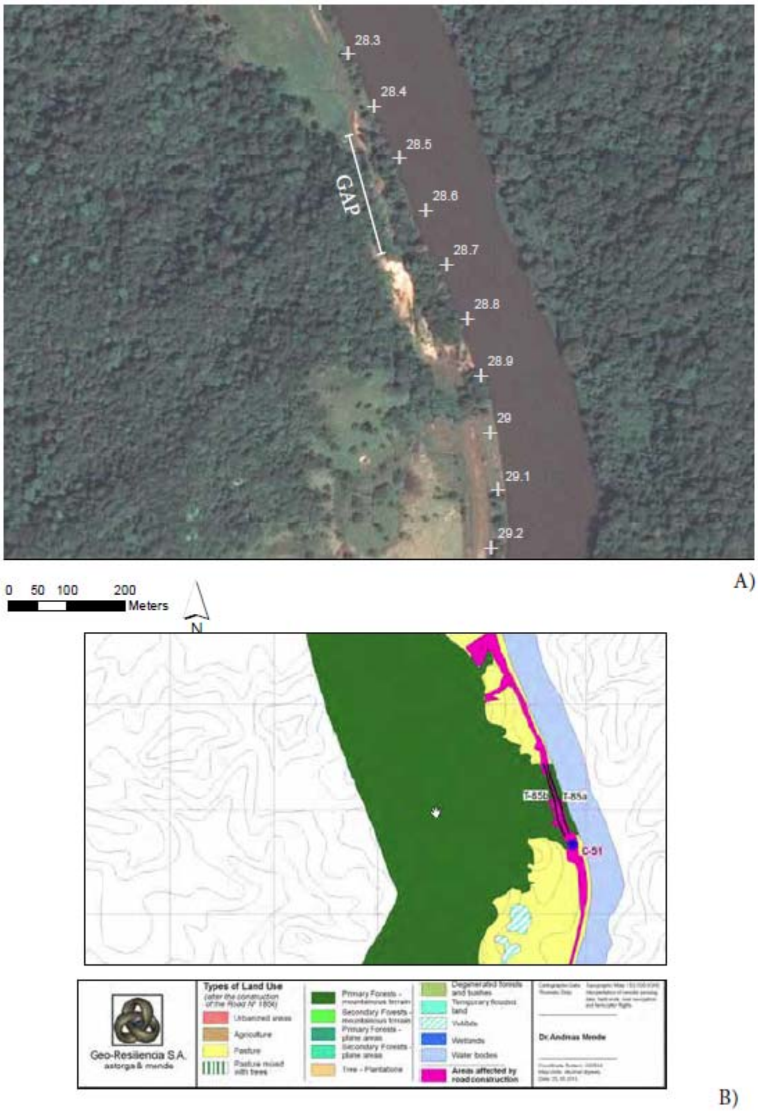
Figure 4. Oblique aerial view of Caño La Chorrera, showing multiple attempts to cross the stream, 23.9 km downstream of Mojon II border marker. White box shows location of the embayment off the main Río San Juan that was formerly a pool under a canopy of trees (as shown in Figure 5a but which is now filled for most recent attempted stream crossing for Rte 1856 (Figure 5b). Photo date: May 2, 2014.

Figure 5. Views from Río San Juan of Caño La Chorrera, 23.9 km downstream of Mojon II.
Photo dates (a) October 20, 2012 and (b) March 31, 2014.

Downstream of Las Cruces

Another gap appears from Rkm 28.4 to 28.9 (Figure 6) (approximately 3 km downstream of Las Cruces), visible in the aerial imagery of 2013. It appears that some initial clearing was done, but the construction attempt was abandoned before major earthwork was attempted. The section from Rkm 28.5 – 28.65 appears as a gap on the Mende and Astorga (2013) maps on p.386. It is not identified as a gap in the road, but can be seen as such in the red footprint of the road disturbance appearing within the straight lines for "slopes" T-85a and T-85b (Figure 6). The lines were drawn continuously through this gap (with red color within the lines), as if to suggest the road was continuous through here, but in fact there is a gap, as clearly visible on aerial imagery.

Figure 6. The gap in Rte 1856 from Rkm 28.4-28.9. A) Detail from Feb 2014 high-resolution satellite image showing the gap. B) Detail from the "slope inventory" map of Mende and Astorga (2013), Annex 6, covering the same area.



El Jardin

Another gap in the road exists approximately 1 km downstream of El Jardin, at Rkm 36.2 – 37.1, where construction attempts were abandoned prior to initiating major earthwork (Figure 7). From Rkm 36.2 – 36.4, some clearing of vegetation was evidently done, but no major earthwork was attempted. The road construction attempt was presumably abandoned because of the disastrous results of attempts to build the road from Rkm 37.1 to 36.4, which resulted in multiple landslides and instability across the entire attempted road segment (Figure 8). The map of Mende and Astorga in Annex 6 (p.387 of Vol. II of the Counter-Memorial) shows multiple parallel red lines and wide red areas in this section of multiple landslides (Figure 7). The parallel red lines presumably indicate multiple failed attempts to construct the road up this slope. Curiously, they also show a thin line of red 'affected' area from Rkm 36.2 – 36.4, implying that the road is continuous through this section but with more restricted impacts. However, it is clear from inspection of the aerial imagery that no earthwork was attempted in this section, and thus it should be recognized as a gap.

<u>Figure 7.</u> The gap in Rte 1856 from Rkm 36.2-37.1. A) Detail from Feb 2014 high-resolution satellite image showing the gap. B) Detail from the "slope inventory" map of Mende and Astorga (2013), Annex 6, showing the same area.

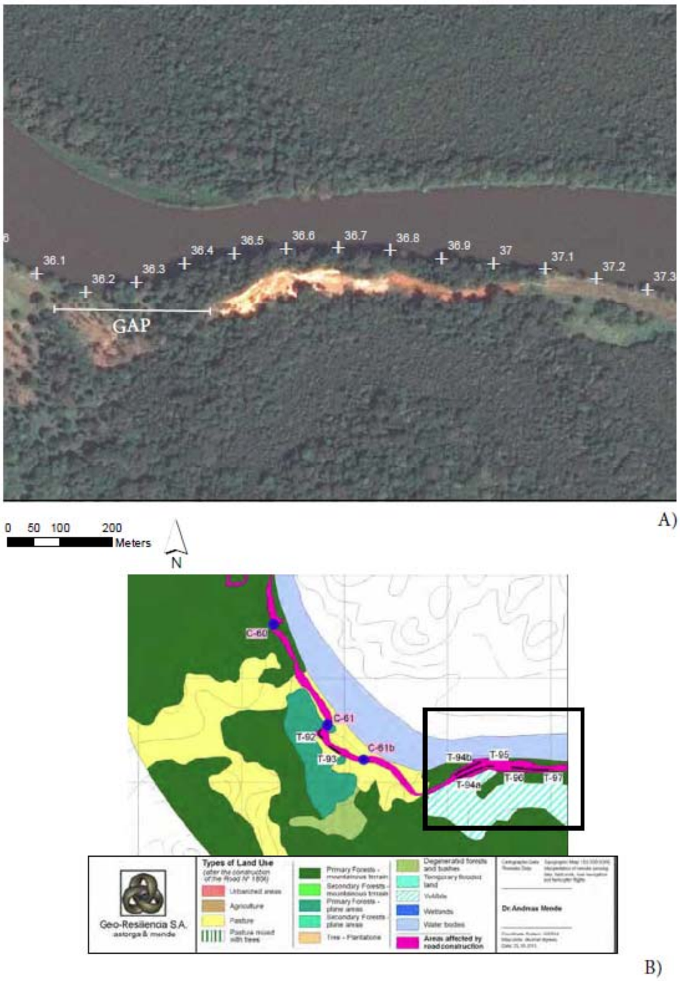


Figure 8. May 2014 oblique aerial view of the failing slope
1 km downstream of El Jardin (Rkm 36.4)

3. The Situation is Worsening, Not Improving.

The reports submitted by Costa Rica imply that conditions have improved along Rte 1856. For instance, the November 2013 Environmental Diagnostic Assessment ("EDA") states that the risk of slope erosion and slope instability "has been controlled," and that to avoid the collapse of stream crossings, "a periodic monitoring effort has been conducted … promoting adequate preventive control of the structures along the way." (Annex 10, p.30). The EDA also states that "runoff control systems have been put into place, as well as sediment traps along the Route" in order to prevent the "risk of eroded sediments depositing on bodies of water." (Annex 10, p.30). Similar statements implying improved conditions appear elsewhere in Costa Rica's submission as well (e.g., Annex 1, p.2; Annex 6, pp.28-29; Thorne, Section 11).

However, erosion has visibly worsened since I first observed Rte 1856 in October 2012. The progression of erosion and delivery of large quantities of sediment to the Río San Juan is obvious in sequences of aerial (helicopter) photographs and cloud-free satellite imagery that has become available.

The Inventory of Severely Eroding Sites included as Appendix A to this report, and the analysis on continuing erosion presented below, show massive, continuing erosion, lack of any serious efforts to stabilize slopes and control erosion, and continued delivery of sediment to the Río San Juan. These problems are sufficiently significant to be visible from space. For instance, sequential satellite images show the progression of erosion of exposed road from approximately 17.9 to 18.3 km downstream of Mojon II (in the area known as Las Crucitas) from November 2012 to December 2013 (Figure 9).

Figure 9. Progression of erosion at Las Crucitas, 17.9 to 18.3 km downstream of Mojon II. (a) Satellite image of November 2012 shows erosion has already begun on fillslopes and stream crossing fill prisms since construction. (b) Satellite image of December 2013 shows significant progression of erosion, with expansion of a gully complex at the stream crossing fill prism "A", and washouts of stream crossings "B" and "C".

Since my report of 2012, the availability of high-resolution, cloud-free imagery has greatly improved,[3] such as Pleiades imagery, which we obtained from Spatial Solutions, in Bend, Oregon USA. The imagery was orthorectified to a 1:25,000 NMAS standard (US National Map Accuracy Standards) using the best publicly available digital elevation model (DEM). Orthorectification is the process of geometrically correcting aerial or satellite imagery to remove distortion due to topographic relief, lens distortion, and/or camera tilt. An orthorectified image ensures uniform scale and allows for the measurement of true distances and areas in a Geographic Information System (GIS). With these high-resolution, ortho-rectified images, we can now identify and measure many large erosional features visible from space.

In addition, since my first site visit in October 2012 and the report of 2012, I have returned to Río San Juan on three more occasions, in May 2013, October 2013, and May 2014. These return visits have allowed me to observe the continued erosion of the road from a helicopter above the north bank of the Río San Juan and re-photograph eroding sites to document changes over the period Oct 2012 – May 2014. Photographs taken from the helicopter looking across the river (referred to as 'oblique' aerial images because they are not oriented vertically downward, as with satellite imagery) clearly show the progressive erosion of large areas of the road.

In some cases, where erosion features are visible (e.g., not obscured by trees), by combining information from the satellite and repeated, oblique helicopter photos, we have been able to make precise measurements of the horizontal dimensions of features at the eroding sites, allowing us to quantify with confidence the size of many features and to document the occurrence and magnitude of gullies and failures over this period. For horizontal dimensions, we used orthorectified satellite imagery from December 2013 (0.5-m resolution) and February 2014 (1.5-m resolution), in conjunction with the previously used but partially cloud-obscured imagery from September/October 2012 (0.5-m resolution). For vertical scale we identified features on repeat oblique aerial imagery from Oct 2012 and May 2014, using existing features nearby such as buildings and trees, or drawing upon photographs with figures standing near features presented by Mende and Astorga (2013) in Annex 5, and referencing heights reported from field estimates by Mende and Astorga (in the ACCESS database supporting Annex 6, provided by Costa Rica on 21 May 2014, in response to Nicaragua's data requests of 21 January and 25 March 2014). On the basis of these measurements, we have estimated unstable fill volumes and erosion rates since late 2012, a period of only modest rains, for sites readily visible from satellite imagery and oblique aerial photographs.

There are too many severely eroding sites to describe them all in detail in this report, so the reader is referred to Appendix A, the Inventory of Severely Eroding Sites (SES), for a list of more such sites. The SES Inventory is not a comprehensive inventory of all eroding sites along Rte 1856, but a compilation of those that are most visible from space and from a helicopter across the river. When vast areas of tropical soils are de-vegetated and disturbed by bulldozers, as has occurred in the disorganized attempt to construct Rte 1856, erosion by impact of tropical rainfall is inevitable over the entire disturbed surface. This surface or sheet erosion from the impact of individual rain drops is too small to be seen from space (unless the

[3] Professor Thorne implies at pp.52-55 of his December 2013 report that I have manipulated satellite imagery. This is false. A letter on point from the provider of the satellite imagery is attached to this report as Appendix B.

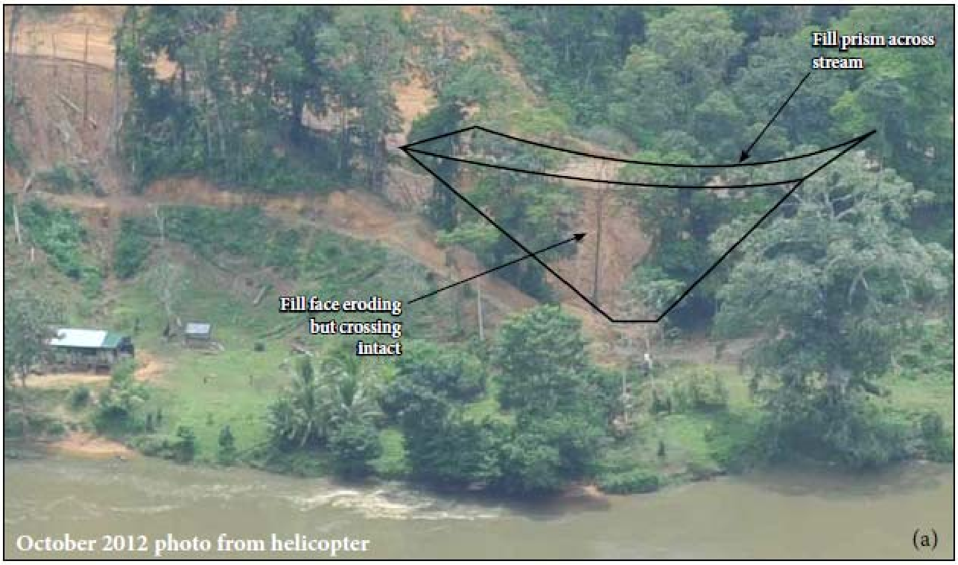
erosion coalesces into large, visible gullies), but cumulatively it is very significant. Here, I document ongoing erosion (and the measurements and calculations used to derive erosion volume) at five severely eroding sites: three examples of stream crossings, and two sites with both cut and fill slopes. For each, I present repeat oblique aerial views from 2012 and 2014, along with high-resolution vertical aerial imagery from 2013. The images are annotated to indicate features such as the 'prisms' of earth that constitute the stream crossings. (The features such as stream-crossing fills, cut- and fillslopes created in this kind of road construction I described in detail in my 2012 Report, pp.10-14).

The erosion documented at these sites has occurred since the attempted construction of Rte 1856 in 2011, with continued erosion since October 2012, during a period of relatively modest rainfall. Professor Thorne agrees, saying "the post-Road period has been drier than usual" (Thorne, ¶ 8.12); "considering that the last two years have been drier than average, [the UCR erosion rates] could be exceeded in the future" (Thorne, ¶ 8.32).

Thus, the Río San Juan has not experienced the kind of rainfall intensities that will occur during major storms (such as tropical storms and hurricanes – discussed in more detail in Section 12, below), which are the conditions that trigger the most failures from disturbed areas (Larsen and Parks 1997, Larsen and Roman 2001, Maharaj 1993, Douglas 1967, Tan 1984, Hicks 1991, Kansai et al. 2005).

Stream Crossing at Eroding Site 9.4 (18.0 km downstream of Mojon II)
The fill prism for this stream crossing, as I first viewed it from a helicopter in October 2012, was at least 15 m high and 70 m of road length across at the top, totaling approximately 21,900 m^3 in volume (Figure 10a). The fill face was visibly eroding (by rills, gullies, and sheet erosion), but the fill prism was intact. The culvert for this fill is not visible in the 2012 photograph, probably obscured by trees. However, it was apparently undersized and/or poorly located, because it ultimately failed.

Figure 10. Eroding Site 9.4, 18 km downstream of Mojon II.
Oblique aerial views from October 2012 (a) and May 2014 (b).



By December 2013, the crossing had failed, leaving a void space approximately 1,722 m^3 in volume, representing a volume of sediment eroded from the crossing and carried down the slope towards the river. This is a significant volume of sediment, the equivalent of roughly 215 standard dump truck loads (of 8 m^3). The path of the sediment traveling from the failed crossing to the river is visible on the high-resolution satellite image (Figure 11), as is the delta built of this sediment that has entered the Río San Juan.

Figure 11. Eroding Site 9.4, 18 km downstream of Mojon II.
High-resolution satellite image of December 2013.

The road culvert was transported with the sediment into the river. Pieces of this culvert were removed by Nicaraguan crews (Figure 12).

Figure 12. Nicaraguan staff working in delta prograding into Río San Juan to remove plastic pipe washed out of stream crossing fill at Eroding Site 9.4. Photograph date: October 27, 2013. Provided by the Government of Nicaragua.

The pieces of culvert were the most visible indication of the failure, but most of the 1,722 m^3 of sediment was carried into the river, some remaining behind as part of the newly expanded delta deposit. This failure was only one component of erosion from the crossing; the total erosion, which included the sheet, rill, gully, and landslide erosion, is considerably more. Hagans and Weaver (2014) estimate that the site is experiencing an additional 1,145 m^3/yr of additional rill, gully and landslide erosion, and an additional 517 m^3/yr in surface erosion, for a total of 3,384 m^3/yr from the entirety of Severely Eroding Site 9.4.

A subsequent photograph taken in May 2014 shows that the failed part of the road crossing has been refilled (Figure 10b). However, the crossing is not properly drained, as water has ponded behind the crossing and is flowing down across the face of the fill, which will erode and destabilize the fill. Also visible in this view are continued landsliding on the slope below the road and trees freshly fallen as a consequence. Clearly, this is not a section of road suitable for traffic, especially heavy trucks carrying potentially hazardous materials, as discussed in Section 5, below. The delta built of sediments eroded from this failed crossing is also visible. The delta is larger in this view than in the October 2012 view, both because it has received material from the 1,722 m^3 sediment pulse caused by the failure of the road crossing fill prism, and because the photo was taken at lower water, so more of the delta is exposed than at high river levels.

Stream Crossing at Eroding Site 9.5 (18.1 km downstream of Mojon II)
The fill prism for this stream crossing, as I first viewed it from a helicopter in October 2012, was at least 18 m high and 45 m of road length across at the top, totaling at least 12,000 m^3 in volume (Figure 13a). As in the prior example, no culvert for this fill is visible in the 2012 photograph. However, if it existed, it was apparently undersized and/or poorly located. The fill material appears to have been simply dumped and pushed in place by trucks and bulldozers, and not compacted or otherwise engineered and its slopes stabilized, as would be required by international standards (FAO 1998).

Figure 13. Eroding Site 9.5, 18.1 km downstream of Mojon II.
Oblique aerial views from October 2012 (a) and May 2014 (b).

In the December 2013 vertical aerial imagery, large-scale failure of the fill is evident (Figure 14).

Figure 14. Eroding Site 9.5, 18.1 km downstream of Mojon II.
High-resolution satellite image of December 2013.

Most of the 2,860 m^3 of sediment from this failure (the equivalent of approximately 357 dump trucks) was carried into the river, with some contribution to the newly expanded delta deposit. Once again, this failure is only one component of erosion from this crossing; the total erosion, which includes all sheet, rill, gully, and landslide erosion, is considerably more. Hagans and Weaver (2014) estimate that the site is experiencing an additional 775 m^3/yr of additional rill, gully and landslide erosion, and an additional 350 m^3/yr in surface erosion, for a total of 3,985 m^3/yr from the entirety of Severely Eroding Site 9.5.

By May 2014, when I took the photograph in Figure 13b, the fill failure had been filled in and a new culvert placed in the fill. The refilled crossing as reconstructed is not as wide as the original crossing, or it may have been rebuilt to the same width and partially failed by May 2014. A small culvert is visible within the prism of the rebuilt crossing. This culvert appears to be grossly undersized and is improperly located such that it is perched far up in the fill prism, likely because landslides on the slopes upstream of the crossing have filled the former stream valley with sediment and blocked the original culvert (if one existed), which was presumably at a lower elevation. The crossing perched high in the fill is an inherently unstable location because of the likelihood that water will seep around the pipe and cause it to fail again. This poses a severe risk for any vehicles attempting to drive over the fill, let alone transport hazardous materials here, as discussed in Section 5, below.

Also visible in the May 2014 photo is the sediment delta deposited along the south bank of the Río San Juan (Figure 13b). This delta consists primarily or entirely of sediment eroded from the road, as is evident from the fact that the sediments on this delta consist dominantly of angular, friable fragments of deeply weathered rock. These weak fragments are clearly from the nearby road construction because they would break down into sand, silt, and clay if they were transported any significant distance.

The fill for this crossing was evidently not engineered, its slopes were not stabilized, and if a culvert was used, it was evidently too small for the flows and not protected from debris jams, as demonstrated by its failure. The reconstructed road crossing appears to be comparably deficient and thus vulnerable to similar failure in the near future.

Stream Crossing at Eroding Site 9.6 (18.2 km downstream of Mojon II)
This stream crossing is 100 m downstream of Site 9.5, described above. The fill prism for this stream crossing when I first viewed it from a helicopter in October 2012 was approximately 20 m high and 65 m of road length across at the top of the prism, for a total volume of approximately 44,000 m^3 (Figure 15a). Visible in the October 2012 photograph is an undersized culvert, perched approximately one-third of the way up within the fill prism. Normally a culvert would be larger for such a crossing and located at the base of the fill, along the grade of the original streambed. Already in the October 2012 photograph active erosion and slumping of the fill face are visible, but the crossing itself is mostly intact.

Figure 15. Eroding Site 9.6, 18.2 km downstream of Mojon II.
Oblique aerial views from October 2012 (a) and May 2014 (b).

The vertical aerial (high-resolution satellite) image of December 2013 shows the development of three adjacent gullies (Figure 16). Taken together, the gullies measure 80 m across (in the direction parallel to the river bank), and 50 m horizontally from the headcuts down to the foot of the fill slope. The volume represented by these three gullies – the volume of sediment already eroded from the stream crossing fill prism – totals about 6,600 m^3, or about 15% of the original total fill volume. This is a truly massive quantity of sediment, the equivalent of about 825 dump truck loads. Once again, the total volume of erosion from the site would include additional erosion outside the gullies themselves. Hagans and Weaver (2014) estimate that the site is experiencing an additional 1,081 m^3/yr of additional rill, gully and landslide erosion, and an additional 488 m^3/yr in surface erosion, for a total of 8,169 m^3 – or a total of over 1,000 dump truck loads – per year from the entirety of Severely Eroding Site 9.6.

Figure 16. Eroding Site 9.6, 18.2 km downstream of Mojon II.
High-resolution satellite image of December 2013.

The photograph I took in May 2014 (Figure 15b) shows a fresh landslide on the cutslope hillside in the upper right of the view (with no apparent efforts to stabilize it), continued construction of an access road descending from the road in the middle right of the view, and two deltas built up from sediment eroded from the road. The delta on the right is the same delta as appeared in Figure 13b, and consists of sediments eroded from the stream crossing at Eroding Site 9.5, 100 m upstream. The delta on the left consists of sediments eroded from the crossing at Eroding Site 9.6, mostly from the three large gullies. Continued gully erosion is evident on the surface of the road and the side slopes. This stream crossing is clearly not fit for use by vehicles.

Cut and Fill Slopes at Eroding Site 8.1 (16.1 km downstream of Mojon II)
When I first viewed the cut and fill slopes at this site, in October 2012, the cuts appeared relatively fresh, and the cut slope had experienced a shallow failure, evidenced by an arcuate headscarp (i.e., a gently arc-shaped scarp marking the point of detachment of a landslide) over 70 m across, i.e., parallel to the river (Figure 17a). Hagans and Weaver (2014) report the landslide area as measured in GIS to be 1,300 m^2. Conservatively estimating the landslide to be at least 2 m in depth and using the average slope height of 25 m reported by Mende and Astorga (2013, Annex 6), the volume of the landslide (which occurred between the time of construction and October 2012) would be approximately 2,600 m^3.

<u>Figure 17.</u> Eroding Site 8.1, 16.1 km downstream of Mojon II.
Oblique aerial views from October 2012 (a) and May 2014 (b).

October 2012 (a)

May 2014 (b)

The fill material had been sidecast, i.e, pushed over the side by the bulldozer blade, rather than being engineered. This is evident from the loose texture of the fill material exposed, and the arcuate pattern of failure. To the right and left of this fresh failure, closely-spaced rills and gullies are visible in the fill slope. At this time (October 2012) the cutslope above the fill appeared to be intact. Already, the site appears to be impassable by vehicles. It is not clear where vehicles are intended to go: presumably the top of the fill, but with the failure, that surface is too narrow to support traffic, and even if it were wider, it would be too unstable to support heavy loads. The fact that failure was already in evidence in October 2012 demonstrates the fill's loose, uncompacted nature: much like a sand pile, unsuited to support vehicular traffic.

The high-resolution aerial image of December 2013 shows development of multiple gullies, including a large one under the letter A, with a surface area of approximately 110 m^2 and depth of about 3 m. This indicates the volume that eroded over the preceding year from this feature alone was approximately 330 m^3 (Figure 18).

Figure 18. Eroding Site 8.1, 16.1 km downstream of Mojon II.
High-resolution satellite image of December 2013.

By May 2014, when I took the photograph in Figure 17b, the entire fill slope had developed a complex of gullies, rills, and shallow landslides. The gully under point A on Figure 17b is visible, as well as deep (though less wide) gullies to the left edge of the view. Also visible are gullies forming in the cutslope above the fill. Hagans and Weaver (2014) estimate that outside of the landslide, the site is experiencing 1,072 m^3/yr of additional rill, gully and landslide erosion, and an additional 484 m^3/yr in surface erosion, for a total of approximately 1,556 m^3/yr from the bare portions of Site 8.1 that are not covered by the most severe erosional features. I note that their figures do not include surface erosion from the surface of the landslide, even though by May 2014 this surface was covered in gullies, rills, and shallow landslides. Thus, the Hagans and Weaver figures are conservative and understate the erosion from the site.

It is clear that no erosion control or slope stabilization measures have been undertaken at this site, which continues to worsen and to deliver sediment to the Río San Juan. Any attempt to pass vehicles over this site would be extremely unsafe.

Cut and Fill Slopes at Eroding Site 8.2 (16.2 km downstream of Mojon II)

In October 2012, when I first viewed this cut and fill slope complex, the fill slope evidenced multiple shallow failures, rills, and gullies (Figure 19a). Two massive arcuate head cuts are visible in the left side and center of the view. Hagans and Weaver (2014) report that GIS measurements indicate lengths parallel to the river of approximately 50 m for both failures, and surface areas of 1,079 and 1,049 m^2, respectively. Assuming a 1.75 m average depth, these two prism-shaped failures together involved the loss of approximately 3,724 m^3 of sediment, which would fill about 465 dump trucks. Also visible in the 2012 image are sediment deposits at the toe of the failure, sediment left behind in the transfer of this sediment to the San Juan River. As of 2012, some shallow failures had already developed in the cutslope above, but their development was limited.

Figure 19. Eroding Site 8.2, 16.2 km downstream of Mojon II.
Oblique aerial views from October 2012 (a) and May 2014 (b).

The high-resolution satellite image of December 2013 shows possible continued propagation of the headcuts and unambiguous development of gullies across the entire fillslope (Figure 20).

Figure 20. Eroding Site 8.2, 16.2 km downstream of Mojon II.
High-resolution satellite image of December 2013.

The oblique helicopter photograph from May 2014 shows the same gullies visible on the December 2013 imagery, but with greater detail (Figure 19b). Also visible is the development of landslides on the cutslope, which have undermined and caused trees to fall. Hagans and Weaver estimate that outside of the two large landslides, the site is experiencing an additional 1,332 m^3/yr of rill, gully and landslide erosion, and an additional 601 m^3/yr in surface erosion, for a total of approximately 1,933 m^3/yr from the bare portions of Site 8.1 that are not covered by the two landslides. However, it is clear from the 2013 and 2014 images that the landslide surfaces are covered with rills, gullies, and possibly shallow landslides. Thus, the site experienced two large landslide failures in the fillslope between construction and October 2012 (which eroded over 3,700 m^3), and in each subsequent year surface erosion, rilling, and gullying exceeding another 1,900 m^3, for an average of approximately 3,200 m^3/yr from Site 8.2.

Summary Comments

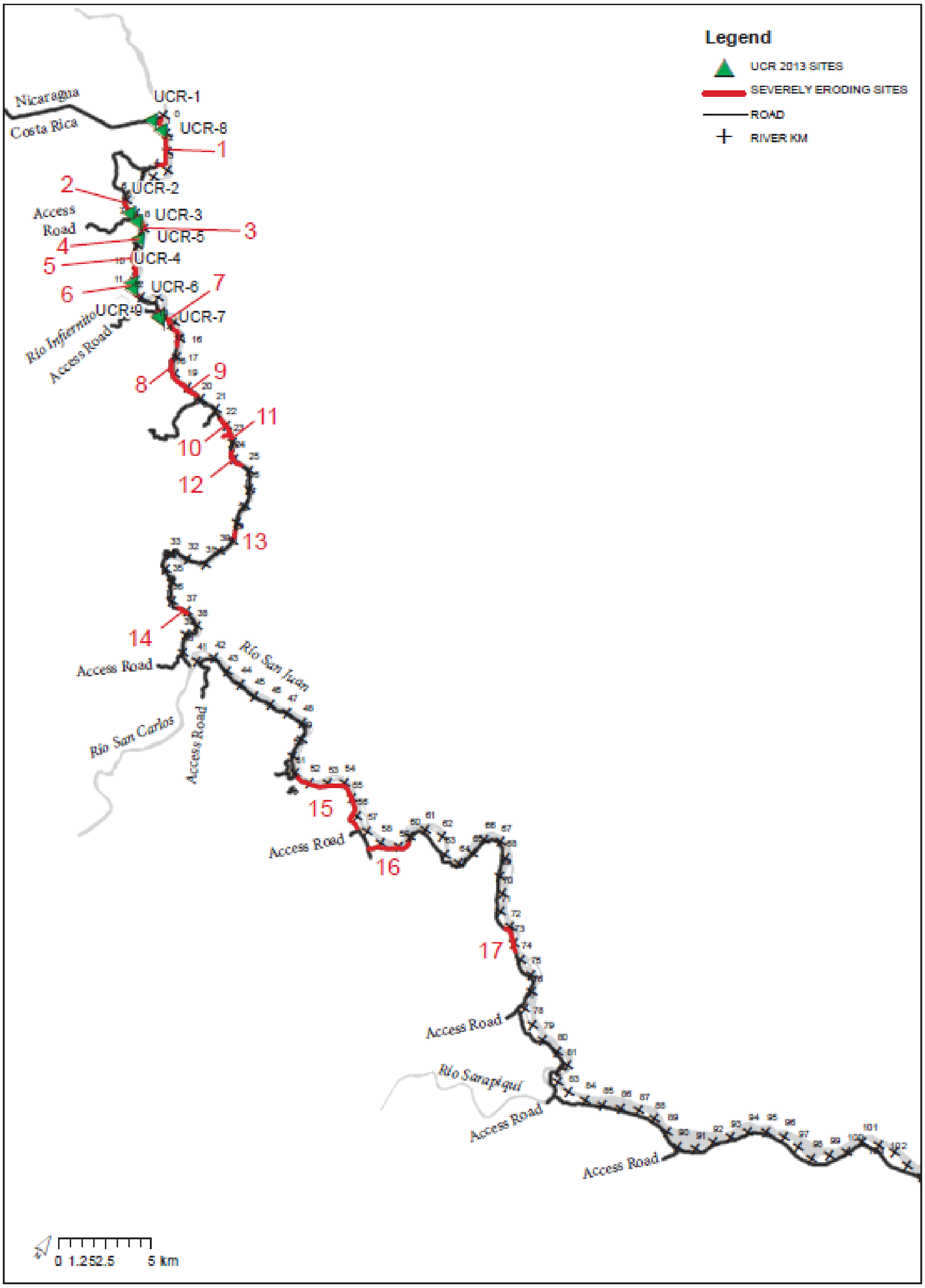
One of the most striking features of all the features documented here is the lack of effort to stabilize the fill piles or undertake repairs based on sound engineering practice. Despite the evident failures, the repairs to date are limited to partially refilling the culvert washouts and installing small culverts high in the fill, where they are certain to wash out again.

These are only a few examples of the widespread erosion and failure of the unprotected cut and fill slopes, and the deterioration of fill-based stream crossings, that are visible along Rte 1856, even from helicopter and satellite imagery. Additional examples, covering a total area of approximately 788,038 m^2, are included in the Inventory of Severely Eroding Sites, appended to this report as Appendix A. Figure 21, below, plots those sites in red on a map of the portion of Rte 1856 that is adjacent to the San Juan River.

The fact that so much erosion and landsliding has occurred, and that multiple culverts have washed out, in response to the modest rainfall since the land disturbance caused by construction activities for Rte 1856 only demonstrates the vulnerability of the areas disturbed by such construction.

As I have explained previously, the practices employed to build Rte 1856 have set the stage for extensive mass wasting during the next period of intense rains. Specifically, the massive, unengineered cuts in hillslopes, un-engineered fill prisms (created through side-casting), and massive, un-engineered earthen fills for stream crossings, are prone to failure under saturated conditions. The sites described above, and others illustrated in Appendix A, are not ready to face intense rain events (tropical storms or hurricanes), nor are they stable enough to hold up reasonably during an earthquake. This issue is discussed in more detail in Section 12, below.

Figure 21. Map of Severely Eroding Sites along Rte 1856 from 2014 Inventory (Appendix A), and locations of the UCR (2013) erosion sites.



4. The Magnitude of Failure Along Rte 1856 is Not "Typical" and Reflects Widespread Violations of Established Standards.

Mende and Astorga (Annex 6, p.29) state that "the present condition of the slopes along the border road between Mojón II and Delta Costa Rica can be considered to be typical of a road under construction." At p.28, they also characterize the current condition of stream crossings along Rte 1856 as "typical during a construction period."

I disagree with these characterizations. As detailed above, cutslopes and fillslopes have experienced extensive landslides and rill/gully erosion, and the road is unusable because of such failures in multiple locations. In addition, many of the stream crossings of Rte 1856 are poorly constructed of substandard materials, and many have already failed (sometimes more than once). This is not "typical" for construction projects.

It is not "typical" to have multiple stream crossings fail within the first few years after construction. It is not "typical" to have multiple fill slopes fail within a year or two of construction, nor to have massive gullies develop on fill slopes and stream-crossing fills. In the US, such violations result in severe penalties for the perpetrators, and we would hardly consider these destructive actions "typical." They represent a level of incompetence and blatant disregard for environment and safety that has already impacted the Río San Juan, and poses even more significant threats from future contamination by chemical spills (Section 5, below) and massive failures triggered by future intense rains or earthquakes (Section 12, below).

The construction of Rte 1856 was a large project carried out immediately adjacent to the Río San Juan. None of the normal, expected safeguards against environmental damage were taken. The road was not planned, and no environmental impact analysis was carried out prior to the project (CFIA 2012). Not only were there no plans developed for the entire route, there were none for individual sections, most of which were built by different contractors. It is apparent that bulldozer operators would simply "wing it", in many places attempting to put the road up steep slopes that in a normal road building project, with standard engineering and environmental safeguards, would never have been selected for a road in the first place. For instance, from Rkm 36.4-37.1 (approximately 1.5 km downstream of El Jardin) bulldozers attempted to build a road up a steep slope adjacent to the Río San Juan, repeatedly destabilizing the slope and shifting their attempts to the right or left, until the result was a disorganized complex of multiple scars and active landslides (Figure 8). I should emphasize that there is no road here, only the eroding aftermath of an attempt to build one, which served no beneficial purpose and was entirely unnecessary. A road should never have been attempted up such an inherently unstable slope, certainly not so close to a river. The multiple, adjacent attempts to construct the road, depicted by parallel lines within a wide area of disturbance on the map of Mende and Astorga (2013, Annex 6, p.387 of Vol.II) reflect a fundamental lack of understanding of site conditions and disregard for the damage caused by the repeated attempts to build the road here. This site continues to fail and erode, with no apparent efforts to stabilize it.

As documented in my 2012 report, based on GIS analysis of aerial imagery, nearly half of Rte 1856 is within 100 m of the river bank, virtually guaranteeing that much of the sediment eroded from the road would be readily transported to the river. 30% of the road is within 50 m of the river bank, which creates greater impacts, and which is in violation of Costa Rican regulations as well as international norms.

Construction of Rte 1856 involved multiple cut and fill roads across steep hillslopes, many underlain by weak rock types or with unfavorable orientation of geologic structure, resulting in inherently weak cutslopes. The material removed from the cut was simply 'sidecast', i.e., pushed down the slope by the blade, without first removing vegetation from the slope and with neither engineering the fill by compaction nor use of geotextiles. As a result, the fillslopes are inherently unstable, no more than loose piles of earth, easily eroded into rills and gullies by surface runoff, and prone to landsliding. For instance, from Rkm 8.2-8.7 (Severely Eroding Site 4), the bulldozers cut into hills well within 100 m of the river bank. As visible in Figure 22a, the bulldozers simply took the material cut from the hillslope and dumped it down the slope below, creating an unstable slope of loose fill, with multiple shallow landslides (which can be seen to be eroding the edge of the road) and gullying/rilling over the entire fillslope. Likewise, from Rkm 16.1-16.4 (Severely Eroding Site 8), it is clear that the fill material was simply sidecast off the road in loose piles, which by October 2012 had developed three large landslides in the fill (described in detail in Section 3 above) (Figure 22b).

<u>Figure 22</u>. Examples of sidecasting fill material. a) Severely Eroding Site 4 (Rkm 8.2-8.7) (photo from helicopter over north bank of Río San Juan, October 2012). b) Severely Eroding Site 8 (Rkm 16.1-16.4) (photo from helicopter over north bank of Río San Juan, October 2012). It is clear from the loose, failing nature of the fill slopes that the bulldozers simply dumped the material down the slope below, creating an unstable slope of loose fill vulnerable to landsliding, gullying, and rilling.

Similarly, the stream crossings consist of loose, unengineered fill dumped over what most commonly appear to be undersized culvert pipes, which are often not set at the base of the fill (along the original grade of the stream) but higher in the fill, where they are more prone to failure (as has occurred at many crossings).

In addition to the specific problems of steep slopes and stream crossings, the road was poorly constructed overall, especially in that drainage is badly designed where it exists at all (CFIA 2012, LANAMME 2012). Good drainage is important for any road but especially for dirt or gravel roads, which are prone to erosion and washout from concentrated runoff. Moreover, ponding of water in ditches or upstream of stream crossings can cause saturation and elevated pore pressures in fills, leading to fill failures. This was likely a factor contributing to the failure of stream crossings at Severely Eroding Sites 9.4 and 9.5 (described in Section 3 and illustrated in Figures 10-14). The fact that water is visibly ponded behind the stream crossing at Site 9.4 in the May 2014 photo (Figure 10b) suggests that this site is highly vulnerable to further failure.

As explained in my 2012 report, construction of a cut-and-fill road such as Rte 1856 disturbs the natural infiltration of rain that occurred in the natural, vegetated hillslope and disrupts the natural drainage patterns, leading to more rainwater running off the surface and concentration of this runoff. The concentrated runoff, in turn, is very effective in eroding the exposed soils. Even with good drainage, a road such as Rte 1856 will result in increased erosion rates. When good drainage is lacking, as is the case along the vast majority of Rte 1856, the problems are compounded as runoff accumulates and often creates new channels draining towards the river, which carry substantial loads of sediment. For example, the quarry located at Rkm 25.3 km has had no erosion control or slope stabilization measures, nor any drainage features constructed. Sediment-laden runoff from the exposed quarry surfaces drained towards the Río San Juan, and by May 2014 had eroded a small channel to carry this runoff (Figure 23).

Figure 23. Surface erosion of a quarry for road construction materials located at Rkm 25.3 km (downstream of Mojon II). No erosion control, slope stabilization, or drainage measures were visible as of May 2014. Sediment-laden runoff from the exposed quarry surfaces drained towards the Río San Juan, and by May 2014 had eroded a small channel to carry this runoff and sediment into the Río San Juan. (Photographs taken from helicopter over the north bank of the Río San Juan.)

October 2012

May 2014

5. Much of Rte 1856 is Not Safe for Use.

In its current condition, Rte 1856 upstream of Boca San Carlos cannot be driven at all except for short sections, and even those portions that are drivable pose safety problems. This is not surprising in light of the fact that the road was not planned, so there was no way that safety standards for factors such as maximum acceptable slopes, sharpness of turns, security of stream crossings, road drainage, and sloping of the road could be incorporated. The implications for the Río San Juan are potentially profound. One of the cargos to be carried by trucks on a functioning Rte 1856 would likely be petroleum. It is not difficult to imagine the weight and vibration of a gasoline tanker causing failure of a fillslope or stream crossing, or the overly steep grades and too-sharp turns in this unplanned road causing a truck to overturn. The resulting spill and contamination of the Río San Juan could be devastating. Besides petroleum, chemical fertilizers, herbicides, and pesticides (heavily used in the Rio San Carlos and Sarapiqui basins) are likely to be transported by trucks on Rte 1856, and all could have devastating effects, above and beyond the impacts of sediment eroded from the road. Spills of petroleum and agricultural chemicals (heavily used in Costa Rica) would poison aquatic life, killing many organisms outright, affecting growth and reproduction of others, and contaminating fish upon which local residents depend.

Unsafe Stream Crossings

Unsafe portions of Rte 1856 include stream crossings, many of which are substandard. As noted by LANAMME (2012)[4] and CFIA (2012)[5] and confirmed by our aerial reconnaissance and inspection from the river, many stream crossings could most charitably be termed "informal." This is confirmed by the inventory of stream crossings presented by Mende and Astorga (2013, Table 4, p.28 of Annex 6), which reports that of the 103 stream crossings whose construction has been attempted, only 10 are considered to be in "appropriate" condition. All but one involved placement of earthen fill in the channel, material that is then at risk of washing out. When these crossings fail, which has already occurred in some places and would be likely under the load of heavy trucks, they are likely to result in spills of hazardous material directly into the streams tributary to the Río San Juan (i.e., the streams that are being traversed by these crossings), providing a direct and rapid delivery of contaminants into the river.

Many of these stream crossings have already washed out (as documented above in Section 3), and for others, the construction technique and material used are visible. None appears to be a properly engineered bridge crossing. Each crossing should be analyzed for weaknesses, and in most cases completely rebuilt as properly engineered bridges, providing adequate span to allow at least the 100-year flood discharge to pass without problem, and designed to safely

[4] LANAMME pointed to various problematic examples (pp. 33, 40, 44, 45, 46), citing the "poor management of waterbodies crossed by the route" as "one of the issues of greatest concern" (p.34). LANAMME noted that improperly constructed stream crossings could erode the roadbed and fills and cause breaks in the road (pp.34, 49), but also that the improper construction of stream crossings "causes a negative impact on these bodies of water, limiting oxygenation capacity and degrading water quality as a result of stagnation" (p.34). LANAMME recommended: "This type of provisional measures should be replaced as soon as possible with culverts properly designed according to ... each stream flow rate to prevent eventual road embankment damage during the rainy season" (p.40).

[5] For example, CFIA noted "a bridge comprised of two trailer containers and wooden logs. The walls of the trailer containers are already bulging and in imminent danger of collapsing" (p.9). CFIA (2012) also noted "bridges built with logs of wood" (p.16), "bridges built out of wooden logs and trailer containers" (p.21), "round plastic pipes" (p.21), and "road wide enough for only one vehicle" (p.21). CFIA noted that "trailer containers already reflect deterioration and are risk of collapsing" (p.26).

support the weight of vehicles likely to use the road. Designing and properly constructing adequate bridges will require engineering designs, in all likelihood utilization of materials such as metal, concrete, and possibly chemically-preserved railroad ties, rather than the local logs, trailer containers, and plastic pipes that have been utilized to date on Rte 1856, and which "…do not comply with minimal structural design and engineering mechanics requirements." (CFIA 2012:27) Further, it will require competent contractors to build them, under the supervision of the design engineers with relevant experience and expertise. Substituting proper bridges for existing, failing earth-fill stream crossings will require that the fill be removed to a stable disposal site.

While many failed stream crossings were constructed in steep terrain, the poorly built crossings of Rte 1856 are vulnerable to failure even on flat ground. The tributary crossing at Rkm 20.3 (i.e,. 20.3 km downstream of Mojon II) is illustrative. Located on flat floodplain, this was a minor bridge spanning a small stream (Figure 24a). Its construction presumably involved earthen fill to narrow the stream width to be spanned by the bridge (as was the case for all crossings but one, according to Table 3 in Mende and Astorga in Annex 6, p.27). As visible in Figure 24, the oblique helicopter image of October 2012 and the satellite image of November 2012 show the crossing intact but being eroded from the north (downstream) side. By December 2013, the crossing had completely failed, the crossing had been partially re-filled with unengineered fill, and a small footbridge had been installed to allow crossing by pedestrians, dirt bikes, or donkeys, but not vehicles. The fill material washed out from the crossing was transported down to the Río San Juan, where it created a new delta, as visible in Figure 25. This delta incorporated white plastic pieces of the failed culvert, as visible in Figure 25. Based on measurements in GIS of the area of the crossing washout and a height estimated from the field observations (from the river), the failure produced a sediment pulse of approximately 480 m^3 of fill material, which was enough to build a new delta in the Río San Juan. This crossing failure illustrates that the stream crossings for Rte 1856 are vulnerable to failure not only because of steeply sloping lands, but even in flat lands because of the substandard construction practices (see CFIA 2012 and LANNAME 2012 for further description of unacceptable and dangerous construction methods). The poor construction practices implemented on Rte 1856 all but guarantee further failures and further delivery of sediment to the Río San Juan. It is worth bearing in mind that these failures and sediment delivery to the river have occurred during years with relatively modest rainfall, and that much greater erosion is inevitable during the intense rains that will accompany a hurricane or tropical storm in the region.

Figure 24. Helicopter and satellite imagery of failed fill crossing 20.3 km downstream of Mojon 2 border marker. a) The oblique helicopter photo of October 2012 shows evidence of headcutting. b) The November satellite 2012 imagery shows the same situation: headcutting but the fill still mostly intact. c) By December 2013, satellite imagery shows the crossing had failed completely. A temporary single-track crossing had been placed over the channel, and fill material had been placed in the channel to re-narrow the crossing, but the culvert had not been replaced and water was flowing freely over the loosely compacted material. The plastic pipe culvert washed out and was transported down to the Río San Juan along with the eroded sediment, as illustrated in Figure 25.

Figure 25. Photographs from a field visit in March 2014 show a delta of sediment with pieces of the failed culvert extending into Río San Juan. New fill material was placed in the channel to partially fill the void created by the failure, but no new culvert was installed.

Appendix C presents an inventory of potentially unsafe stream crossings that should require assessment by qualified experts to determine level of hazard and to recommend repair or complete replacement with properly engineered bridges before being considered safe for passage by vehicles. We identified the crossings as being potentially unsafe using information available from aerial imagery and observations from the river, based on placement of unengineered fill within the channel, use of unacceptable materials, likely inadequate flood capacity, and/or prior history of failure. However, our list (based on our limited information) is clearly incomplete, because Mende and Astorga (2013, Annex 6, p.28) report 16 crossings as "closed," 9 as "broken," and 42 as "provisional" for which "technical improvements are recommended within the near future," for a total of 67 crossings that are either failed or unsafe, compared to only 10 in "appropriate" condition.

Unsafe Steep Slopes

Other portions of the road are unsafe because of steep slopes: both the steep slopes of hillsides across which road construction has been attempted, and the steep slopes of some sections of the road itself (where completed in hilly terrain), which creates difficulties for safe passage of vehicles. The road segments crossing steep slopes have an elevated failure potential of sidecast, unengineered fills, which are widely failing already, prior to the application of loads, and will be more likely to fail when subjected to the loads of heavy trucks. CFIA (2012:26) recommended, "Stabilization of the slopes with high margins and significant dimensions in order to avoid landslide during the rains that are about to begin."[6]

Even if the road does not fail outright, the excessive slopes in many parts of the road, owing to the lack of planning or adherence to environmental or safety standards, pose a serious hazard of overturning trucks and collisions due to the difficulty in controlling heavy vehicles on overly steep grades. The FAO recommends "keeping the road grade as low as possible…Maximum grades of 10 to 20 percent (6^o to 11^o) are recommended in some countries…" (Dystra and Heinrich 1996). Yet CFIA (2012:26) noted that along some sections of Rte 1856, "transit is almost impossible due the very elevated longitudinal slopes." As noted by the FAO, such steep roadbed slopes not only create hazardous conditions for driving, but also higher maintenance costs and more erosion problems (Dykstra and Heinrich 1996).

Appendix D to this report presents an inventory of potentially unsafe slopes.

Proximity to Río San Juan

The problems with unsafe and unstable slopes and poor stream crossings are compounded by the extreme proximity to the Río San Juan of most of the route. Most of the steep slopes traversed by the road are within 100 m of the river, many much closer, so that failure of these slopes and overturning of trucks carrying hazardous material are very likely to result in immediate contamination of the Río San Juan, with essentially no opportunity for first responders to control the contamination or block its pathways, because the area is remote and difficult to access, and because once onsite, responders would have difficulties accessing the riverbank itself, or setting right a heavy, overturned truck down a steep slope.

As recommended by the FAO, a basic principle of road construction is to keep "roads and disturbance areas away from streams" (Dykstra and Heinrich 1996). As noted above, our GIS analysis (reported in our 2012 report) showed 50% of the road is located within 100 m of the river, and 30% within 50 m. The maps presented by Mende and Astorga in Annexes 3 and 6 of the Costa Rica Counter Memorial likewise show the extreme proximity of Rte 1856 to the Río San Juan. CFIA (2012) reported the road was only 10 m from the river in places and that this should be corrected (p.9), and "There are stretches of the road where its path is very close to the bank of the Río San Juan, these stretches of the road should be re-evaluated" (p.13). It recommended "evaluation of the recesses of Río San Juan by way of a technical study under present applicable law."

[6] CFIA (2012) also highlighted the problem of "steep slopes [i.e., cutslopes] up to approximately six meters high with very elevated margins" (p.9), "huge slopes with high peaks and no protection whatsoever," and observed "areas with cracks and holes, besides very elevated longitudinal slopes" and "slope approximately six meters in height with almost vertical slope" (p.15).

Reducing the Hazard
To reduce the hazard posed by this unsafe road, the entire existing road would need to be inspected and objectively analyzed by qualified road engineers. In some sections of the road, such as those on steep slopes adjacent to the river bank, the road should simply be moved inland to less inherently risky routes, and the damaged portions of the landscape repaired by stabilizing the cutslopes and hauling away fill material to minimize future sediment delivery to the Río San Juan. Other parts of the road can probably be stabilized in the current alignment or with minor realignments, but most of the actions described in my earlier report on urgent measures, and described in detail in the 2014 report of Danny Hagans and Bill Weaver of Pacific Watershed Associates, will need to be implemented to stabilize these road sections.

Appendix E presents sites where Rte 1856 is too close to the river bank and in steep terrain, a combination of conditions that strongly indicates the road should be moved, based on our GIS analysis conducted in 2012. (Inspection of the maps presented by Mende et al. in Annex 5 and Mende and Astorga in Annex 6 also shows the road is very close to river in general agreement with our mapping.) From Mojon II to Boca San Carlos, 5.1 km of the road is in steep terrain within 50 m of the river bank, with an additional 12.7 km within 100 m. From Boca San Carlos to Boca Sarapiqui, 1.9 km is in steep terrain within 50 m of the river, with an additional 2.1 km within 100 m.

One section of road that should be relocated is the section of rapidly eroding road in steep topography downstream of Rio Infiernito, as recommended by the Environmental Diagnostic Assessment (EDA) submitted by Costa Rica (Annex 10 to Costa Rica's Counter-Memorial). The EDA noted the "occurrence of landslides and slope erosion affecting the forest borders of the road." The EDA recommended measures include, "To evaluate the technical possibility of modifying the route designated for Route 1856 at the point called Infiernillo [sic] to include the use of local roads built on less sloping terrain, tracing the road some km. to the south, where there are open areas and settlements with more favorable topographic conditions" (EDA, p.147). Although the precise section of road to be relocated was not specified, the implication is that the entire section from approximately river km 14 to 20 (i.e., from approximately 14 km to 20 km downstream of Mojon II) would be involved.

6. Meaningful Remediation Has Not Been Attempted.

Professor Thorne states (without providing a citation) that in my second report, "Dr Kondolf notes that most of the road bed has now been covered in gravel, which will further reduce erosion of the road itself, especially in relation to that from cut and fill slopes." (Thorne, p.71) I have never, and cannot, state that "most of the road bed has not been covered in gravel," because this is not true. It is also not true, as Costa Rica's reports imply (e.g., Thorne, Section 11; Annex 1, p.2; Annex 6, pp.28-29; Annex 10, p.30), that real mitigation has been undertaken along Rte 1856.

Most of Rte 1856 has not been subject to erosion control efforts. Of the 41.6 km from Mojon II to Boca San Carlos, only the upper 15 km of the road have had erosion control attempts. The road is graveled down to approximately Rkm 14.5 and for another 0.5 km (until the first gap in the road appears), informal track (i.e., pre-existing pathways for foot and animal traffic, mostly on flat land over which a 4x4 vehicle can be driven, but not a road vehicle) (see description of gaps in Section 2). Downstream of this point, the road is not passable in many places, and disturbed areas have been left exposed to the elements, with no apparent erosion control efforts.

Thus, much of Rte 1856 continues to erode, with large landslides, gullies, and surface erosion (as documented in Section 3 and Appendix A). On the sites with the greatest ongoing erosion rates and greatest potential for future erosion, no erosion control has been attempted. Genuine steps to stabilize unstable cutslopes and to remove unstable fillslopes and road crossings would involve significant earth moving and geotechnical stabilization, as detailed by Hagans and Weaver. This would be an effort of an entirely different magnitude than the surficial erosion control attempted to date.

Even on the upper 15 km where erosion control has been attempted, these attempts have been superficial, attempting to treat only symptoms, with no attempt to control ongoing or potential landslides. Many of these measures have failed. As noted in my report of 30 October 2013, *Continued Impacts of Erosion from Rte 1856, Costa Rica to the Río San Juan, Nicaragua,* the erosion control measures include covering bare-earth roads with rock (done down to Rkm 14.5), lining ditches adjacent to the road surface, installing concrete lined drains along the inside and outside portion of some road segments, covering some steep fill slopes and cut slopes with erosion control fabrics, and seeding and planting some areas, including attempts to establish vegetation in small circular holes in cutslopes. These are the measures discussed in the Counter-Memorial, presented in Annexes 2, 7 and 8, and described by Thorne (2013, pp.109-116). While these measures may reduce surface and gully erosion from the few treated areas during small and moderate rains, they will do nothing to prevent massive failures of cut slopes with unfavorable rock type and geologic structural orientation, nor will they prevent mass failure of un-engineered fillslopes and stream crossing fill prisms, which are most likely to occur during intense rains.

Annex 2 includes photographs of a tree-planting program, but does not provide essential information such as whether the plantings will actually address slope stability issues (the answer in most cases will be no, because the failure planes of landslides would be deeper than the rooting depth of plants), and whether the plants have survived since planting (in our observations from the river, it appeared that most have died).

The erosion control measures we observed in most cases were deployed only to control surface erosion from roads themselves, have failed in many places, and in others are actually counter-productive. For example, putting gravel or crushed rock on top of the road surface and installing drainage ditches can help to protect the road surface itself from erosion, but the concentrated runoff that results must be managed safely, and this has not been done along Rte 1856. As I noted in my October 2013 report, in May 2013, I observed a new concrete drain approximately 11.8 km downstream of Mojon II immediately after an intense rain. The concrete ditch was directing runoff from the graveled road directly onto the fill slope, eroding the fill slope itself, which is the foundation for the road (Figure 26a). In May 2014, the fill slope on which the runoff had discharged had eroded severely, and displayed a large washout (Figure 26b).

Figure 26. Photo of road runoff directed from drainage structure into fill in May 2013 (a), and resulting erosion in May 2014 (b).


(a)


(b)

Properly designed and constructed road drainage structures should always convey the runoff at least to the base of the fill slope or farther. They should not discharge flow onto the fill. This error illustrates the evident lack of knowledge behind the erosion control efforts.

Many eroding slopes have been covered with black plastic sheeting. This approach is unsuitable for steep slopes and cannot address fundamental problems of slope stability. Moreover, this plastic sheeting deteriorates rapidly from ultra violet rays, and at most of the sites where it was installed, the sheeting is at least partially failed (Figure 27).

Figure 27. Failing black plastic erosion control fabric approximately (a) 6.8 km and (b)10.0 km downstream from Mojon II, respectively.


(a)


(b)

The inept and failing erosion control efforts, undertaken on only the first 15 km of Rte 1856 below Mojon II, contrasts with the impression Costa Rica conveys with its list of mitigation measures on pp.42-46 of the Counter-Memorial, many photographs of small erosion control projects (Annexes 7 and 8), and descriptions of volunteer planting efforts (Annexes 2 and 7).

With regard to the CONAVI Report, the compilation of erosion-control photographs that has been submitted with the Counter-Memorial as Annex 8, many of the photographs have no locational information associated with them and lack coherent explanatory text. The photos appear to show projects to protect the road surface, but do little or nothing to protect fillslopes and the river downstream. Moreover, not stated in the report is the fact that these erosion control projects were undertaken on parts of the road that, while eroding, were not the most serious problems. These erosion control projects are attempts to treat surface erosion only, and do not address the vulnerability to stream-crossing fill washout and landsliding that will occur during intense rains. Costa Rica's reports (Annexes 2 & 7) contain no images of the many failed plantings visible from the river, no data for percentage survival of these plantings, and more importantly, no acknowledgement that even if they survive, such plantings can never stabilize slopes against most landslides, because the landslide failure planes are much deeper than the root depth of even successfully established trees.

In summary, while the techniques employed to control erosion by Costa Rica may help control surface erosion, they have been poorly applied (e.g., Figures 26 and 27) and to only a limited section of Rte 1856. They are inadequate in that most of these methods protect only the road surface and do not control runoff onto the fill, and more fundamentally, they do nothing to reduce the likelihood and severity of landsliding. Moreover, they have been installed only on portions of the road that have suffered less erosion and are still drivable. No erosion control efforts have been constructed on severely eroding sites downstream.

Professor Thorne makes no attempt to defend the way Rte 1856 was constructed, and his apparent endorsement of Costa Rica's ongoing erosion control efforts is highly nuanced. Although Professor Thorne implies that he has faith that Costa Rica's efforts would be sufficient for real erosion control, all he actually seems to say is that Costa Rica's efforts have made things a bit better than they were when the road was a freshly-cut, bare scar on the landscape.

I previously noted the following statement by Professor Thorne on this topic: "It is my understanding that the measures I observed in May 2013 are part of ongoing efforts intended to reduce erosion risks stemming from the way the Road was constructed in 2011 and that they are not intended to provide a permanent solution to erosion issues. Given that, my experience suggests that with appropriate inspection and, where necessary, maintenance and repair, the mitigation works will significantly reduce local erosion rates for the next year or two, allowing time for the work necessary to design, contract and build permanent works to progress." As I explained in my November 2013 report, *Comments on Costa Rican Submissions* (p.13), this is confirmation of my fundamental point that Costa Rica's erosion control measures will not actually solve Rte 1856's erosion problems. Professor Thorne repeated this statement in his most recent report (¶11.18) and added the following at ¶11.19: "However, these are temporary works that mitigate but do not permanently solve erosion problems, and a permanent solution will not be achieved until design, planning and construction of the Road are completed. In my opinion, the necessary work should proceed as soon as possible, with the work expedited to the greatest degree, and consistently with Costa Rican legal and contracting practices." Professor Thorne and I agree: work needs to be done as soon as possible to solve existing erosion problems.

Another portion of Professor Thorne's discussion of Costa Rica's erosion control efforts bears emphasis. He says that those efforts will reduce erosion rates for the next year or two assuming there is "appropriate inspection and, where necessary, maintenance and repair." As the examples of Severely Eroding Sites 9.4, 9.5, 9.6, 8.1, and 8.2 demonstrate (see Section 3 of this report), that "maintenance and repair" have not been undertaken.

Professor Thorne also argues that "the rate of erosion will decrease further in future compared to that reported in the UCR Report and that the Road will become increasingly insensitive to heavier rainfall as time passes." (Thorne, 2013, p.115) He cites a study on St John, US Virgin Islands by Ramos-Scharron and Mac Donald (2005), which showed that the rate of erosion from unpaved roads decreased with time since the last grading. This effect applies only to surface erosion from unpaved road surfaces, not to developing gullies or to landslides that may be triggered by future intense rains. Moreover, the main point of Ramos-Scharron and MacDonald (2005) is the tremendous effect of roads in increasing erosion:

> "The measured erosion rates indicate that unpaved roads on St John can increase hillslope-scale sediment production rates by more than four orders of

> magnitude relative to undisturbed conditions. The road erosion rates measured on St John are at the high end of reported road erosion rates, and this is consistent with the high rainfall erosivities, steep slopes, poor design, and inadequate maintenance of many of the unpaved roads on St John."

(Ramos-Scharrón and MacDonald 2005: 1301). The conditions described for the roads in St John apply to Rte 1856: "high rainfall erosivity, steep slopes, poor design and inadequate maintenance." The more relevant lesson to draw from this research on St John is that a road such as Rte 1856 can increase erosion rates over undisturbed conditions by a factor of 10,000. (An order of magnitude is a power of ten, so four orders of magnitude = 10,000.)

Curiously, instead of substantive actions to control erosion and stabilize the most seriously eroding sites, I was surprised to see instead continued construction along Rte 1856 of power lines. In 2012, we observed a power line extending along Rte 1856 between 4 and 7 km downstream of Mojon II. In May 2014, we observed it to extend down to Rio Infiernito, a total distance of 14.1 km.

7. Costa Rica's Experts Underestimate How Much Sediment this Project is Contributing to the Río San Juan.

Although the approach presented in the Costa Rican reports (Annexes 1, 3, 4, 5, and 6) is difficult to follow, my understanding is that the reports were intended to work together in the following way:

- The UCR Report (Annex 1) measured rates of erosion of various types of features which were said to "represent 'worst case' examples of erosion by land sliding, sheet erosion, rilling and gullying that exist along Route 1856" (Annex 1, p.2). These measurements, which took place between June and August 2013, were used to calculate a general erosion rate for each feature type.

- Then Mende and Astorga (Annex 6) inventoried and estimated the dimensions of all cut and fill slopes (excluding the road surface) occurring along Rte 1856. From the field, they estimated the percentage (by area) of each type of erosional feature affecting each slope, and supposedly applied the UCR Report's rates to them, thereby calculating "worst-case" total erosion annual erosion rates for each slope disturbed by construction of Rte 1856, and a total rate for all of the slopes along Rte 1846. The erosion rates for "slopes" were presented by site and summed in Annex 6.

- ICE (Annex 4) incorporated total erosion from slopes from Annex 6, along with an estimate of surface erosion from the road itself (applying an erosion rate from the UCR Report in Annex 1 to the area of the road) in their overall sediment budget "to estimate overall erosion and sediment delivery from Route 1856 to the San Juan River system" (ICE 2013).

The UCR Report's Low Erosion Rates
Annex 1 to the Counter-Memorial is the "Report on Systematic Field Monitoring of Erosion and Sediment Yield along Rte 1856" prepared by a civil engineering professor and an undergraduate student from the University of Costa Rica. It presents data collected from sediment traps and other erosion studies at selected sites along Rte 1856 upstream of Rio Infiernito, from June-September 2013, ultimately providing erosion rates that are repeated in Professor Thorne's report (¶¶8.21-8.41) and the Counter-Memorial (¶¶3.20-3.24).

Annex 1 was first provided in connection with the hearings that took place in November 2013. I conducted a preliminary review then and provided an initial critique in my November 2013 *Comments on Costa Rican Submissions* (pp.3-6). The report has been resubmitted with the Counter-Memorial, and it appears to be unchanged from the document I reviewed and critiqued previously.

The assertions in Annex 1 that landslides and gullies do not occur together on fill slopes (Annex 1, pp.15-16) is not true. To the contrary, gullies and landslides occur on the same fill slopes in many locations along Rte 1856, as can be seen, for example, in the images of Severely Eroding Sites 8.1 and 9.4 discussed in Section 3 above (Figures 17-18 and 10-11). One need only examine Appendix A of Annex 6 to the Costa Rican Counter Memorial (pp.405-408) to find multiple sites where Mende and Astorga (2013) recorded both landslides and gullies on the same fill slopes. The assertion in the UCR Report that landslides and gullies do not occur together on fill slopes makes no sense scientifically and seriously undermines the scientific credibility of the report.

Annex 1 also states that the sites it studied "represent 'worst case' examples of erosion by land sliding, sheet erosion, rilling and gullying that exist along Route 1856." (p.2).[7] In his November 2013 report (Annex 9 to the Counter-Memorial), Professor Thorne likewise stated that "it is reasonable to assume that the recorded rates of land surface lowering [reported in Annex 1] represent 'worse case' scenarios for Road-related erosion to date," apparently on based on the idea that the rates were derived from the study of, among other things, "the two largest rotational landslides observed along the Road" and "the slope which displayed most intense rill (micro-channel) erosion" (¶33). Similar statements are repeated in Annex 6 (p.31) and Annex 4 (e.g., p.28). All of these statements are incorrect.

The sites assessed in the preparation of Annex 1 were all within the first 15 km of the river-adjacent Rte 1856 (i.e., between the international border and Rio Infiernito). Even within that stretch, the sites studied are not the "worst" sites of erosion. Figure 28 shows the extent of erosion in the cut-and-fill slope exposed from Rkm 10.4-11.3 (Severely Eroding Site 6a, in Appendix A), which is within the 15 km stretch in which all the UCR Report's study sites exist.

[7] In claiming that its erosion rates are "highly conservative," Annex 1 also states that "most slopes and fills in the study area have been protected with geotextiles and been subject to re-vegetation or (where possible) reforestation, and are experiencing much less erosion than the sites selected for study" (pp.1-2). As explained in Section 6, above, most of Rte 1856, including the worst eroding sites, have not been meaningfully protected.

Figure 28. Context of UCR's Site 4 within a larger complex of eroding features from Rkm 10.4 to 11.3. a) Oblique aerial photograph from helicopter, October 2012, showing multiple landslides to the right (west) of the site selected for detailed study by UCR. b) Detail of the same photograph, showing larger eroding features in cutslope, similar to the rills measured by UCR but larger, as well as two nearby landslides. The UCR Report (Annex 1) presented only photos showing close-up views of the section of the rilling cutslope where UCR made its measurements (inset). Note that the UCR photo labeled "b" ended just to the right of much larger eroding features in the cutbank, similar to but larger than those measured by UCR.

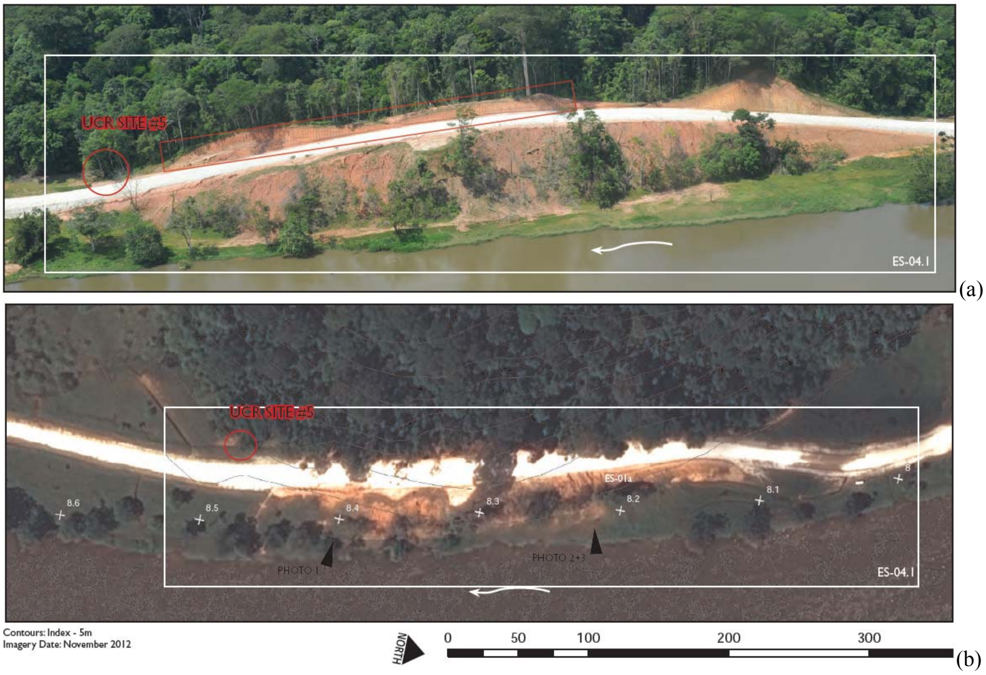
October 2012 (a)

October 2012 (b)

Along this cutslope, multiple landslides are visible in the photo shown in Figure 28, but the UCR Report focused only on a small set of rills developed at one end of this larger site. The UCR Report (Annex 1) included only close-up photographs included as insets in Figure 28a, which show a person taking measurements on the rilling slope. However, the UCR Report did not include an image such as our Figure 28a or b, which help to put the UCR Site into proper perspective. The UCR Report did not include images of the larger gully/rill features just to the right of the one they measured, nor explain why they chose the smaller feature to measure. A broader look at this site shows the riverside edge of the road is uneven and contains multiple irregularities, and broad arcuate features, which can be interpreted as scarps of landslides in the loose, sidecast fill material. These failures are large enough that they have visibly eroded into the original constructed width of the road. It is troubling that the UCR Report measured only the minor rills at the far downstream end of this site and did not address the larger eroding features.

The UCR Report also asserted that, "Fill slopes in the studied area do not feature landslide erosion" (Annex 1, p.17). The report did not define the "studied area," but presuming it to be the first 14 km downstream of Mojon II, within which all the UCR sites were located, this statement is clearly false. For example, the UCR study site 5 was located at the downstream end of a large eroding area from 8.0 to 8.7 km downstream of Mojon II (our Severely Eroding Area 4, see Figure 29 and Appendix A). Beginning less than 100 m upstream from the UCR study site is a series of large landslide failures in the fillslope, clearly visible in the satellite image of November 2012 (Figure 29). If the UCR Report makes the statement that "Fill slopes in the studied area do not feature landslide erosion" because its authors failed to recognize these massive landslides, adjacent to one of their study sites, that does not inspire confidence in the report. If the UCR Report defines "the studied area" as only the specific sites where its authors made observations, then the report is essentially meaningless, because it reports only on carefully selected, mostly trivial erosion sites while ignoring much more significant ones nearby within the same reach of river, and just downstream (as explained below).

Figure 29. Severely Eroding Site 4, 8-8.7 km downstream of Mojon II. UCR Site 5 was located at the downstream end of this eroding area. a) helicopter photo of October 2012, with UCR study site indicated. B) satellite image of November 2012. Note arcuate headscarps in the road fill beginning within 100 m from the UCR study site.



The most fundamental weakness of the UCR study is its failure to measure erosion downstream in the more severely eroding sites. The 15-km study area is limited in comparison to the 106-km extent of Rte 1856 along the river and did not extend downstream into the reach with the worst-eroding sites: the 26-km from Río Infiernito to the Río San Carlos confluence. When we compare the locations of the Annex 1 study sites to the sites documented to have the most severe erosion problems in our erosion inventory (Appendix A), it is clear that the sites studied by UCR did not include most of the more severely eroding sites.

As is evident from the inventory of erosion sites (Appendix A), there are numerous sites whose erosion rates are far worse than those selected for study by the UCR personnel (Figure 30). One km downstream from the terminus of the UCR Report's study area are the serious erosion problems at Severely Eroding Sites 8.1 and 8.2 (at Rkm 16.1, described above and depicted in Figures 17-20), and another 1 km downstream are located Severely Eroding Sites 9.1-9.8 (Rkm 17.2-19, described above and depicted in Figures 10-16). These and other more severely eroding sites are illustrated in Figure 31.

Figure 30. UCR study sites related to landslide, gully, and rill erosion.

UCR Study Sites related to rills, landslides, and gullies

Figure 31. Sites not studied by UCR.

Sites not measured by UCR.

I demonstrated the inaccuracies of the assertions that the UCR study sites represented "worst-case" conditions in my November 2013 *Comments on Costa Rican Submissions* (pp.3-4). In his most recent report, Professor Thorne amends his argument somewhat, shifting to a discussion of representativeness (though he does not acknowledge his mistake). He responds to my point that Annex 1 ignored the worst eroding sites as follows: "Having viewed the entire length of the Road, I consider that the sites which were monitored by UCR were representative of the characteristics of the geology and terrain in the first 41.6 km of the Road downstream from Marker II, and on that basis the erosion they monitored provides a representative indication of the erosion likely to have occurred along the entire length of that stretch of the Road" (¶8.23). As noted above, a review of the Inventory of Severely Eroding Sites and the evidence presented in Section 3 of this report shows that the sites measured by UCR were *not* representative of the many severely eroding sites along Rte 1856.

Thorne also points to the fact that "the sites monitored by UCR were in a section of the Road with the greatest number of landslides and gullies," which he characterizes as another reason that "the results of UCR's monitoring can be taken to be representative of erosion along the first 41.6 km of the Road alongside the River…" (¶8.23). The sites measured in the UCR Report were not in the section with the greatest number of landslides and gullies. A section with far more landslides and gullies begins at Rkm 16, approximately 2 km downstream of the downstream-most UCR site, and 1 km downstream of the end of the functional road.

As shown in Figure 31, the Inventory of Severely Eroding Sites (Appendix A), and Section 3 of this report, there are far worse eroding sites within a few kilometers of the limit of the UCR study sites. By limiting the study to sites upstream of Río Infiernito, Annex 1 excluded the many more severely eroding sites downstream.

Professor Thorne further states that, because "[e]rosion and mass wasting rates along the other 66.4 km of the Road [i.e., downstream of the 41.6 km that was the focus of my 2012 Report] are certainly much lower than they are in the area studied by UCR," it is "reasonable to assume first, that the recorded rates of land surface lowering approach 'worst case' scenarios for Road-related erosion to date…" (Thorne 2013b, p.73, Vol II:p.219) This assertion makes no sense. I agree that there are far fewer sites of severe erosion downstream of Boca San Carlos (although this lower part of the road is not without erosion problems, as explained below). However, it does not follow that the rates of "land surface lowering" reported by UCR "approach 'worst case' scenarios for Road-related erosion to date." This is a non-sequitur. The first clause in Thorne's sentence does not logically lead to the second.

Moreover, the techniques employed in the preparation of Annex 1 are best suited to stable sites with small erosion rates, not to sites experiencing extreme erosion and landsliding, where the entire site is failing or at risk of failure. However, it is precisely the worst sites that need to be addressed in such a study. These are the sites that will produce the greatest erosion, not only on a chronic basis now, but especially during intense rains that will inevitably accompany tropical storms and hurricanes in the region. Having ignored the more severely eroding sites, Annex 1 presents erosion rates that are too low both for the type of features reported generally and for eroding areas along Rte 1856.

The authors of the UCR Report also applied a flawed methodology. Rather than directly measuring all significant erosion features within the areas experiencing significant erosion and mapping the occurrence of smaller features such as areas of rilling (thereby collecting real data for the sites of significant erosion), they used a complicated system to take their measured erosion rate for a feature such as a gully, and then reduced the rate by dividing it over the area of the entire exposed "slope" in which it occurred. This was effectively an arbitrary reduction to the rate because the size of the exposed area in which the eroding feature occurred was unrelated to the eroding feature itself. The authors of the UCR Report also did not account for other erosional processes occurring over the rest of the slope, which artificially reduced the resulting erosion rate. This is a principal reason that the erosion rates reported in Table 6 of Annex 1 are unreasonably low.

For example, UCR measured gullies at two sites, UCR Site 8 with a single gully, and UCR Site 9 with 16 gullies. At UCR Site 8 (approximately 1 km downstream of Mojon II, and within our Severely Eroding Site 1A), the gully was measured to have a surface area of 121 m^2 with an average depth of 1.5 m, which was assumed to have been eroded over a 6-month period. Consequently, the total annual lowering rate was 3 m. However, UCR then divided the volume of sediment removed from this gully by the entire area of bare, exposed slope at this site, which was stated to be 3,080 m^2, and reported the resulting, very small number as "average" gully erosion rate. However, this is *not* the gully erosion rate. The rest of the bare, exposed slope was prone to surface erosion, and so either surface erosion over this large area should be estimated from field evidence or a reasonable rate should be applied from the literature. The total erosion from the site would be the erosion measured in the gully (without dividing it over the entire site area) plus the surface erosion estimated/measured over the rest of the exposed slope.

Nor is it proper to divide the volume of gully erosion by the entire area of a given site, since the rest of this exposed area is subject to sheet erosion, which as acknowledged in Annex 1, is a different process. The gully erosion rate should be left intact, and a sheet erosion rate should be applied to the rest of the site, where sheet erosion would be the dominant process.

Finally, there is no scientific justification for applying the depths measured in small gullies to large gullies. Erosion rates for each feature should be independently measured, rather than extrapolated from what is an absurdly small sample of unrepresentative sites.

Mende & Astorga Low Erosion Estimates for Slopes

<u>Unsupported Erosion Rates</u>
In Annex 6 to the Counter-Memorial, Mende and Astorga claim to have applied the erosion rates described in the UCR Report to the areas of exposed slope they measured in their field work. Mende and Astorga state their method as follows:

> "Applying the data on erosion depths and rates of land surface lowering due to sheet, rill, landslide and gully erosion reported in UCR (2013), by Oreamuno Vega, M. Eng. and Roberto Villalobos Herrara at the University of Costa Rica, we estimated the sediment yields from all the cut and fill slopes that exist along the border road between Mojon II and Delta Costa Rica."
> (Annex 6, p.1)

In Annex 6, Table 7, Mende and Astorga present their erosion rates. These differ significantly from the rates "recommended" and presented in Table 6 in the UCR report (Annex 1). Comparison of the UCR rates with those used by Mende and Astorga (Table A) shows that Mende and Astorga used higher rates, from 2.6 times higher up to 42 times higher.

Table A. Comparison of erosion rates recommended by UCR Report (Annex 1, Table 6) with rates used by Mende and Astorga (Annex 6, Table 7).

Cut or Fill Slope	Eroding Feature	UCR Study Rate* (m/y)	Mende and Astorga+ Rate (m/y)	Difference
Cutslope	Sheet erosion	0.095	0.095	The same
Cutslope	Rills	0.06	0.17	2.8 times larger
Cutslope	Gullies	0.005	0.21	42 times larger
Cutslope	Landslides	0.19	0.5	2.63 times larger
Fillslope	Sheet erosion	NR	0.24	No UCR rate reported
Fillslope	Rills	NR	0.24	No UCR rate reported
Fillslope	Gullies	0.20	0.75	3.75 times larger
Fillslope	Landslides	NR	1.48	No UCR rate reported

* Annex 1, Table 6 column titled, "Average rate of land surface lowering (m/yr)"
+ Annex 6, Table 7 column titled, "Erosion of 1 m^2 per Year (m)"

In an evident attempt to explain the differences, after stating "the main findings of the [UCR] report are summarized in Table 7," Mende and Astorga (p.6) state, "Nevertheless some clarifications are necessary." This statement is followed by an attempt to explain why they substituted other rates for some of the processes, but does not explain other substitutions.

For example, for sheet and rill erosion on fill slopes, Mende and Astorga used the *gully* erosion rates recommended by UCR, but then increased them by a 20% "margin of safety." They present no justification for taking the rates measured for gullying and using them for sheet erosion. Nor do they justify adding a 20% "margin of safety." How was this so-called "margin of safety" determined? If a "margin of safety" is needed for the estimate of sheet erosion, why is it not needed for other processes for which rates are estimated? This appears simply to be a factor arbitrarily applied to a number that itself is arbitrary in its application to sheet erosion.

Similarly, for gully erosion on fills, Mende and Astorga used a rate of 0.75 m. They did not explain why this rate was chosen, which is much higher than the 0.20 m/yr rate "recommended" in the UCR Report (Annex 1, p.18).

Mende and Astorga (Annex 6) used raw rates of landslide erosion reported in the UCR Report on a cut slope as their rate of landslide erosion for fill slopes, "because these are more unstable than cut slopes." Again, Mende and Astorga's choice of erosion rate is arbitrary. It was not based in any systematic way on the rates recommended by the UCR study, nor on rates reported in the scientific literature. In short, Mende and Astorga do not present a coherent scientific justification for their seemingly random selection of rates to use in different contexts.

While Mende and Astorga used rates that were greater than the rates recommended by the UCR report, they then applied them to areas that were smaller than the true areas of exposed slopes at the eroding sites, as documented below. Thus their approach was not truly "conservative" in terms of developing an erosion estimate that would be at least as large as the true erosion.

The units presented in Table 7 of Annex 6 are not sensible. The third column is titled, "Erosion of 1 m^2 per Year (m)" [sic], which makes no sense. The caption refers to these as "average erosion rate per square meter." However, these should be reported simply as depth of erosion (m). There is no "per square meter" involved. It is properly expressed simply as a depth of erosion per year (m/yr), which can be multiplied directly by the area (m^2) occupied by the features to yield a volume (m^3) of erosion. For example, an erosion rate of 0.5 m/yr for a feature would be multiplied directly by the area of that feature (say 100 m^2) to yield, in this illustration, 50 m^3 total erosion.

Under-Reporting of Eroding Site Areas

In Appendix A to Annex 6, Mende and Astorga list (but do not provide coordinates for) individual "slopes" that were exposed, with their areas, and identifies them as "cut" or "fill." The approximate locations are shown on small-scale maps presented on pp.381-397. The presentation is confusing and difficult to follow.

To get areas of the bare slopes they visited in the field, Mende and Astorga stated, "Slope heights were estimated visually in the field *so that data collection could be completed within a reasonable time span*" (Annex 6, p.4, Vol.II:375, emphasis mine). Thus, rather than measure the actual dimensions of the eroding features, as would be expected in a scientific study, they "estimated visually," justifying this short cut because they did not have enough time. This was an opportunity lost, because basic surveying equipment such as a total station, auto level, and/or laser rangefinder could have been used to provide a more accurate measurement of slope heights. Measurements would have been much preferable to visual estimates to avoid the unreliability of the latter.

Mende and Astorga did not adequately explain how they used these estimated slope heights to calculate their "slope" areas, as would be expected in a proper scientific study. However, from inspection of their database, it appears that they multiplied their estimated average slope height by the length of the feature (e.g., cutslope, fillslope) as measured in GIS, presumably from GPS readings in the field. If slopes were vertical, this method would theoretically be as accurate as the visually-estimated heights used. However, although many cutslopes are oversteepened (and thus inherently unstable), slopes are not vertical, and the less vertical they are, the more this method underestimates actual slope areas. Fill slopes especially tend to have a much lower angle, as loose fill cannot support steep slopes. Thus, to the extent they assumed vertical slopes and failed to account for the horizontal components of the slope when estimating areas (which is particularly important in measuring less steep and highly erodible fill slopes), Mende and Astorga underestimated slope areas. To illustrate, if a fill slope has a 3:1 slope (i.e., slope of 33%), the real area would be twice that calculated via the method that I infer Mende and Astorga used. The result is a gross underestimate of true areas, and because these underestimated areas are multiplied the erosion rates discussed above, the inaccurately low areas results in inaccurately low total erosion calculations.

The magnitude of the potential error from these inappropriate field methods can be assessed by comparing the areas presented in Appendix A with actual conditions on the ground, as measured from satellite imagery in GIS. When the areas measured from the imagery in GIS are compared to the areas of eroding sites provided in Appendix A to Annex 6, significant discrepancies emerge. Table B presents four comparisons between the field estimates of slope areas (used to calculate erosion rates) and areas actually mapped from aerial imagery. The slope areas based on visual estimates in the field range from less than 10 percent to approximately 60 percent of the areas measured in GIS from aerial imagery.

Table B. Example Comparisons Between Areas Reported by in Appendix A of Annex 6 and actual areas measured from satellite imagery using GIS.

Slope ID	Area reported by Mende & Astorga from field estimates (Appendix A, Annex 6) (m^2)	Area measured in GIS from satellite imagery (m^2)
T-066b	1574	4373
T-064b	269	2831
T-057a	532	2495
T-043	4680	7723

The explanation for these significant discrepancies is at least partially attributable to the method used in the field (multiplying the visual estimated slope heights by feature length), but the discrepancies seem to be too large to have resulted from this problem alone. The reader should bear in mind that under-reporting "slope" areas results in the under-calculation of total erosion.

The degree to which Mende and Astorga under-reported the areas of individual eroding areas in Annex 6 is also indicated by comparing the sum of their areas for individual sites with the total area disturbed by the road as shown on their maps. The maps presented in Annex 5 and 6 show an area in red labeled as "areas affected by road construction." The digital files submitted in response to a request from Nicaragua included a GIS "shape file" showing the outline of this area, as a single, large polygon. The area of this polygon is 3,502,180 m^2. Divided by the 108-km road length, this yields an average width of road-impacted area of approximately 30 m, which is plausible. If we subtract from this total the area of a 10 m wide road (108 km x 10 m = 1,080,000 m^2), that would leave 2,422,183 m^2 affected by the road outside the roadbed itself, which would include the cut and fill slopes, quarries, and other areas disturbed by road construction.

Note that these are all numbers provided by the Costa Rican government employees and consultants: 3,502,180 m^2 is the area mapped by Mende and Astorga as having been disturbed by the road construction (from the GIS map files provided), and the 10 m road width is the "average road bed width" reported by ICE (2013, Annex 4, p.29), and the road length of 108 km is reported at various points in Costa Rican documents.

How does the area affected by the road outside of the road itself compare to the total area of exposed slopes obtained by summing the individual "slope" areas reported in Annex 6? According to Appendix A of Annex 6, the total area of "slopes" affected by road construction is only 124,381 m^2 (see bottom of 5th column on the last page of Appendix A of Annex 6, p.408 of Vol.II of the Costa Rica Counter Memorial). This is only 5% of the area obtained by subtracting the area of the road from the total area disturbed mapped by Mende and Astorga.

Thus, examining individual sites (e.g., Severely Eroding Site 9) documents that the "slope" areas visually estimated by Mende and Astorga were much smaller than would be indicated by objectively measuring the areas from satellite imagery. At a larger scale, the sum of these individually under-estimated areas is only 5 percent of the area mapped by Mende and Astorga as affected by the road (outside the road footprint itself) and which would thus be eroding. These are enormous discrepancies. Clearly, there are serious problems with the numbers presented by Costa Rica in these documents.

Underestimated Erosion from Slopes

The result of these problems in Mende and Astorga's approach is an underestimated total yield for slopes. For example, for Severely Eroding Site 9.5, Annex 6 reports a "worst case" erosion rate of 372 m^3/yr, which is said to include sheet erosion, rill erosion, gully, and landslide erosion. However, erosion for the failed fill alone was at least 2,860 m^3 between October 2012 – December 2013, a number that does not include the additional erosion from sheet, rill, gully, and landslides that is evident in the sequential imagery. Hagans and Weaver (2014) conservatively estimate such additional erosion at an additional 1,125 m^3 per year at Severely Eroding Site 9.5.

For Severely Eroding Site 9.6, Mende and Astorga reported a "worst case" erosion rate of 662 m^3/yr, including sheet, rill, gully, and landslide erosion. However, as is clear from the aerial imagery, the complex of three adjacent gullies has produced far more sediment than this, despite the relatively modest rainfall in the preceding years. Based on analysis of our repeat oblique aerial photographs (see Section 3 and Appendix A for details), our estimate from measurements of area and estimates of depths of these gullies alone is 6,600 m^3 – nearly 10 times Mende and Astorga's "worst case" number, much of this having been eroded between October 2012 and December 2013. Thus, Mende and Astorga's estimate is only 10% of the actual sediment yield from the gullies alone. According to Hagans and Weaver (2014), when other surface, rill, gully, and landslide erosion are accounted for on the other 4,845 m^2 of bare soil at the site, the total erosion rate is likely well over 8,000 m^3/yr for Severely Eroding Site 9.6.

The degree to which Mende and Astorga systematically understated erosion rates in Annex 6 is also reflected in the numbers presented by Mende et al. in Annex 5, which often contradict the "'worst case' scenario" rates presented in Annex 6. For example, our Severely Eroding Site 9.4 (Rkm 18) is designated as slope T-68 in Annex 6, which lists a total of 456 m^3 of erosion per year, or approximately 762 tons per year (using a conversion factor of 1.67). This is contradicted by the "Maximum Sediment Production" for this site of 2,250 tons (or approximately 1,347 m^3) per year stated in Annex 5 (p.43). Our Severely Eroding Site 9.6, designated as slope T-72 in Annex and assigned a "worst-case" annual erosion rate of 662 m^3 or 1,106 tons in Annex 6, is stated to have a "maximum sediment production" of 4,500 tons, or 2,695 m^3 in Annex 5 (p.44). Thus, the "maximum sediment production" for these sites reported by Mende et al. in Annex 5 are *three to four times higher* than the "worst-case" rates reported by Mende and Astorga in Annex 6.

The actual *worst-case* scenario for Severely Eroding Site 9.6 is complete failure of the fill prism crossing. In light of the fact that the stream crossings 100 and 200 m upstream (Severely Eroding Sites 9.5 and 9.4, respectively) both failed between October 2012 and December 2013, and in light of the fact that water is likely ponding behind the fill prism at Site 9.6 (as we could see was the case at Site 9.4 in the May 2014 photograph), complete failure of the fill prism at Site 9.6 is a real possibility. If this were to occur, the volume of eroded material would be approximately 37,000 m^3, (i.e., the original fill prism volume of 44,000 m^3 less the 6,600 m^3 already eroded). This volume is more than Mende and Astorga's (2013) "worst-case" estimate for the *entirety* of Rte 1856 (36,715 m^3).

These are not the only sites where Mende and Astorga's (2013, Annex 6) under-reported dimensions of features and resulting erosion rates. Their numbers for Eroding Sites 8.1, 8.2 and 9.4, other sites where satellite and aerial imagery are well suited to making independent measurements, are also under-reported. They also did not include the stream crossing fill washout at Rkm 20.3 in their yield calculation at all, as it was on flat land and not on a "slope."

In sum, there are significant inaccuracies in the numbers presented by Mende and Astorga in Annex 6. These inaccuracies undermine their report and render invalid its conclusions.

Summary

In sum, in addition to ignoring the worst eroding sites, the UCR Report divided the volume of eroding features by the entire area of the slopes on which they occurred (using exaggerated area figures), producing artificially lowered numbers for "average" erosion rates. Mende and Astorga under-reported the site areas and therefore erosion totals. Mende and Astorga claimed to be using rates from the UCR Report, but in reality they arbitrarily substituted different rates, without providing coherent explanations or citations to support them.

It is instructive to contrast these Costa Rican documents with a study of landslide and surface erosion from a road in Yunnan, China, written by Roy Sidle, Takahisa Furuichi, and Yasuyuki Kono. The paper*, Unprecedented rates of landslide and surface erosion along a newly constructed road in Yunnan, China* (Sidle et al. 2011), which is provided as Appendix G, reports on field measurements of surface and landslide erosion conducted along a 4-year old road in the headwaters of the Mekong River. It is clearly organized, simply written, direct in its presentation, and easy for the reader to follow their method and understand their results.

Unlike Mende and Astorga (Annex 6), Sidle et al. made hundreds of measurements of soil erosion from direct evidence, and directly measured the dimensions of landslides in road fills and cutslopes, using surveying tools (e.g., tapes, range finders, and field mapping). They measured features in the field; they did not "visually estimate" slope heights. Unlike the UCR Report, Sidle et al. did not select two individual features of each type to measure. For their 23.5-km section of road studied, for each of three categories of erosion intensity, they measured *all* features within representative 0.75-0.90-km sections of road, which is a more appropriate sample size than the very limited sampling of unrepresentative, small features measured used in the UCR Report. Sidle et al. did not take measured rates from single gullies and divide them over the area of a larger feature. Sidle et al. left their gully erosion measurements intact, without distortion, and did not apply any arbitrary "factors of safety." The rates they reported based on this transparent assessment are much higher than the rates presented by Costa Rica's experts.

Sources of Erosion Ignored in Costa Rica's Estimate

Costa Rica's estimate of erosion from Rte 1856 ignores important factors, such as sediment from stream crossings that are not included in mapped "slopes." (An example is the stream crossing at Rkm 20.3, which blew out over the past year, building a new delta in the river.) Another important oversight is erosional processes on the roadbed itself besides sheet erosion. The assumption that the roadbed will remain stable is contradicted by multiple locations along Rte 1856 where the roadbed is eroding in landslides or massive gullies. The Costa Rican estimate also ignores the contribution from access roads built as part of the border road project, estimated at 332 – 440 km (depending on the Costa Rican source). These extensive access roads all drain to tributaries that, in turn, transport road-increased sediment loads to the Río San Juan. As detailed earlier in this report, the road is not finished, with some large gaps remaining. Resuming construction would lead to further erosion, especially if the route is not reconsidered, and unless completely different construction practices from those used to date along Rte 1856 are implemented.

Nicaragua's Erosion Estimate

My 2012 Report presented an estimate for erosion from Rte 1856 based on one overflight, inspections from the river, and analysis of satellite imagery from 2009 (pre-road construction) and 2012 (post-road construction), the second of which was compromised by cloud cover. As stated in our report, the estimate was based on total areas of various features, multiplied by rates estimated from the literature and our observations of large gullies forming on prominent features visible from the river, such as stream crossing fills (Kondolf et al. 2012: 3-4, 7).

In particular, the erosion estimated we provided related to "the area of steep road cuts and fill for the 41-km section of road upstream of the Río San Carlos confluence. From this, we subtracted (in GIS) the 7-m wide roadbed itself as less likely to fail, and then conservatively estimated that landslide and gully erosion is occurring on 40-50% of the steep disturbed land." (Kondolf et al. 2012: 46) In this limited portion of the upriver stretch, we applied a rate of 1 m, calculating "a total of 218,400 to 273,000 m^3y^{-1} of sediment eroded by mass wasting and gullying." We then assumed a 40% transport rate to the Río San Juan, resulting in an input estimate from landsliding and gully erosion of 87,000-109,000 m^3/yr. We also estimated "surface erosion rates for the upstream 41 km of Route 1856, upstream of Río San Carlos," concluding that surface erosion in that stretch is producing 17,800-21,300 m^3/yr, with 40% of that (7,120-8,520 m^3/yr) reaching the Río San Juan (Kondolf et al. 2012: 45). Thus, we estimated that the upper 41 km of Rte 1856 was contributing 94,120-117,520 m^3/yr.

My 2012 report concentrated on the river upstream of Boca San Carlos because it has the steepest topography and most erosion. My 2012 report nowhere implied that the higher erosion rates we estimated for the upper 41 km of the road would apply to the entire road adjacent to the 108 km of river down to the Delta Colorado. The report was very clear that the estimated rates applied only to the upper 41 km.

The fact that my 2012 Report focused on erosion from the steep upper stretch of Rte 1856 did not suggest that there are no impacts from the road in the 65 km downstream of Boca San Carlos. The widened road will lead to more runoff and surface erosion even in flat sections, and there will likely be more crossing failures such as occurred at Rkm 20.3. There are steep sections downstream of Boca San Carlos that have suffered more severe erosion, as documented in the erosion inventory (Appendix A); there are vulnerable or already-failing stream crossings; and the large extent of bare road surface is subject to sheet erosion. The EDA also identifies "several sites with steep slopes and eroded retention walls" (EDA, p.69). It is incorrect for Professor Thorne to state that there is "nothing to say" about erosion for these downstream reaches (Thorne, ¶5.16), even if rates downstream are lower overall than erosion rates from the steeper reaches upstream.

My 2012 Report mentioned that we had observed sediment delivery from Rte 1856 to the Río San Juan at 54 sites during a helicopter overflight and reconnaissance by riverboat on our site visit of October 2012. This point was made to demonstrate that sediment was entering the Río San Juan from Rte 1856 at multiple points. It did not suggest this was a comprehensive list of such points of sediment delivery to the Río San Juan, or that they are the most important ones. For instance, our view from the river was obscured in many places making it difficult to evaluate erosion from many sites. Costa Rica requested coordinates for these sites, which were supplied. Mende et al. present a critique of these sites, suggesting that 7 of the sites plot in Nicaragua rather than on the south bank of the river, implying that this undermined our analysis. As would be obvious to a professional scientist, as some of the points were identified from the helicopter over Nicaraguan territory, the GPS coordinates recorded would reflect the observer's location rather than the observed point of sediment delivery.

Building upon new data available, our analysis of the 17 inventoried sites of Severe Erosion, and incorporating erosion rates and areas disturbed by road construction presented in Costa Rican reports, we develop a new estimate for the total sediment delivery to the Río San Juan, accounting for additional information, as follows. In the absence of better field measurements conducted systematically over a broader area, and encompassing all larger eroding sites, any exercise in developing estimates of erosion and sediment delivery from Rte 1856 to the Río San Juan will be an estimate based largely on assumptions. One of the most important aspects of any such estimate is that its components and assumptions be clearly stated so that their validity and uncertainty can be evaluated.

Estimate of Sediment Eroded from Rte 1856 and Reaching the Río San Juan
We first measured the areas of the severely eroding sites (SESs), and then subtracted the area occupied by a 10-m-wide roadbed in those stretches on the assumption that gully and landslide erosion occurs mostly on the exposed areas adjacent to the road (i.e., the cut and fill slopes). This is conservative, given that the roadbed itself is failing from landslide and gully erosion in many places, such as Severely Eroding Sites 8, 9, 10, 11, 12, 13, and 14, as documented in Appendix A.

We then assumed that 40% of the non-road area was experiencing active rill, gully, and/or landslide erosion. This percentage of area with such active erosional processes is consistent with assumptions we made in 2012, and is conservative based on the erosion documented from repeated oblique helicopter photography and satellite imagery, which can detect only the most visible erosion. For example, at Severely Eroding Site 8.1 (Figure 17), the oblique aerial photo of October 2012 shows a single large landslide in the loose fill slope, and rills and gullies developed on bare slopes over the entire site. By the December 2013 satellite imagery, one very large gully and many smaller gullies are visible. In the oblique aerial view of May 2014, rills and gullies are visible on the cut bank in the rear, while a set of deep gullies is visible in the left edge of the photo. Under the letter "A" a large active gully has downcut, undermining the banks of the gully, such that the loose sediment is of the banks is falling into the gully proper. To the right of gully "A" there is a broad shallow landslide with arcuate scarp. Thus, the assumption that a mixture of rills, gullies, and landslides affect at least 40% of this site is borne out by analysis of the imagery.

To this 40% area, we applied a generalized, average erosion rate of 0.558 m for rill, gully and landslide erosion, based on a simple average of the average erosion rates for these processes used by Mende and Astorga ((0.205 + 0.48 + 0.99)/3 = 0.558 m/y).[8] This rate is lower than the 1 m/yr rate we used in 2012, and is also conservative given the extent and dimensions of the landslide features and gullies and landslides visible in the imagery. However, only some of these eroding features are detectable from the remote imagery. For a more complete inventory of ongoing erosion, detailed measurements should be made on the ground by qualified, independent scientists. These should be true *measurements*, not visual estimates as made by Mende and Astorga, who did not make actual measurements "so that data collection could be completed within a reasonable time span," as reported in Annex 6.

For the remaining 60% of SES areas (less the 10 m roadbed), for which we assumed no gully and landslide erosion, we applied surface erosion rates for hillslopes adjacent to roads ranging from 0.03-0.06 m/yr, drawn from scientific literature on tropical roads, reporting rates ranging from 0.025 – 0.079 m/yr (DeNoni et al 1987, Hansen et al 19897, Harden 1993, Thomas and Savage 1991).

For the roadbed itself, we applied surface erosion lowering rates from 0.01-0.02 m/yr, drawn from relevant published studies ranging from 0.006-0.023 m/yr (Dunne 1979, Ziegler et al. 2000, MacDonald et al. 2001, Sidle et al. 2004, Ramos-Scharron and MacDonald 2005).

Landslide and gully erosion on the 40% of SES areas sums to 136,515 m^3. To this we added surface erosion from the other 60% of the SES areas. Even though we know that the 40% affected by landslide and gully erosion is still experiencing the impact of raindrops and consequently surface erosion, to develop a conservative number we did not include surface erosion for this area, only the 60% area not included in the 40% area to which we applied the landslide/gully rate. To this area of 367,000 m^2 we applied 0.03 to 0.06 m/yr, which produces 11,000-22,000 m^3 of surface erosion. Adding these two elements yields a total of 147,500 to 158,500 m^3 of total erosion from the SES sites only. Bear in mind that these are only the sites with erosion features readily visible from space, not a comprehensive inventory of erosion.

Turning to the entire length of the roadbed itself from Mojon II downstream, using the stated length of 108 km (which assumes the entire road was built, actually not true), and assuming the roadbed is 10-m wide, this yields an area of 1,080,000 m^2. Applying our range of surface erosion rates drawn from the literature for tropical roads, 0.01-0.02 m/yr, we calculate 10,800 to 21,600 m^3 surface erosion from the length of the road. Note that the 0.01 m/yr rate is only 10 percent of the 0.095 m/yr rate adopted by ICE (Annex 4, p.29) from sediment trap measurements by UCR, reported in Annex 1.

There will be additional erosion from disturbed areas adjacent to the road outside of the 10-m-wide roadbed itself, and outside of the SES areas calculated above. This additional erosion could be estimated using the hillslope surface erosion rates from the literature. The question

[8] In applying the rates specified by Mende and Astorga (Annex 6) we do not imply that these are correct. However, using these rates should allow us to develop estimates for which some of the assumptions are consistent with those developed by Costa Rica's experts, thereby facilitating comparison between the two estimates, and helping us to identify the source of differences between the estimates.

of the area to use is complicated because the areas mapped as having been disturbed by the road, and thus presumably areas vulnerable to surface erosion, are so large. As noted above, the red-colored area 'affected' by road construction shown in the maps in Annex 6 and appearing as a polygon in the GIS files provided by Costa Rica, is a total of 3,502,180 m^2. Divided by 108 km, this is an average width of road-impacted area of approximately 30 m. If we take only the area outside the 10-m wide road, that would average about 20-m width of adjacent slopes affected. Excluding the 17.6 km already included in the SES area calculation, we can roughly estimate the remaining area outside the road as being 108-17.6 = 90.4 km (90,400 m) x 20 m = 1,808,000 m^2. Applying a value for surface lowering for hillslopes adjacent to roads of 0.03-0.06 m/yr, this would yield 54,240-108,480 m^3/yr; applying values for road surface lowering of 0.01-0.02 m/yr, this would yield 18,000-36,000 m^3/yr.

<u>*Adding the components of Rte 1856 erosion*</u>

SES area landslide/gully erosion (on 40% SES areas) =	136,515 m^3/yr
SES area surface erosion (on remaining 60% SES areas) =	11,000-22,000 m^3/yr
Roadbed itself, 10-m-wide =	10,800 - 21,600 m^3/yr
Area outside SES areas and outside roadbed (using lower road surface erosion rates) =	18,000-36,000 m^3/yr

Total erosion from Rte 1856 is thus calculated at from 176,000 to 216,000 m^3/yr.

<u>*Sediment Delivery to Río San Juan*</u>

How much of this sediment will be delivered to the Río San Juan? The concept of sediment delivery is that of the sediment eroded from an upland site, not all will necessarily arrive at the river, because some will deposit along the way. Frequently when erosion is measured at upland sites, only a portion of this erosion actually is delivered to the river. From our observations of sediment going directly into the Río San Juan from failures along Rte 1856, and from the relative lack of sediment storage sites in between the washed-out road crossings, failed fill slopes, and other erosional features and the river itself, it is clear that sediment delivery ratios from Rte 1856 to the Río San Juan are high, much higher than the 40% we conservatively estimated in our 2012 report.

ICE used a higher rate of 60%, which is probably still an underestimate for delivery of sediment from eroding sites near the river, such as the sediment that built the deltas into the river below SES sites 9.4, 9.5, and 9.6, or the sediment that washed out of the stream crossing at Rkm 20.3, where sediment delivery is probably 80% or greater (given the lack of large deposits of sediment visible between the road and the river).

Assuming a conservative sediment delivery ratio of 60%, the total sediment delivery to the Río San Juan would range from 106,000 and 130,000 m^3/yr.

<u>*Additional Sediment from Access Roads*</u>

In additional to Rte 1856 itself, Costa Rica constructed extensive access roads connecting Rte 1856 with points south. The total length of these access roads newly constructed or "improved" is reported as 332 km to 440 km (Annexes 31 and 34 of Nicaragua Memorial). In our 2012 report, we did not include any estimate of sediment generated by the access roads, but focused only on the border road Rte 1856 itself (and focused primarily on the section along the 41.6-km of river upstream of Boca San Carlos). However, all these access roads drain to streams and rivers that eventually drain northward into the Río San Juan. Thus erosional impacts of these access roads ultimately contributes sediment to the Río San Juan.

To develop a rough estimate of the amount of sediment likely generated by the access roads, we can multiply the length by an average impact width. For the Río San Juan, the average impact width was about 30 m (calculated by dividing the total area disturbed by road construction reported by Mende and Astorga (2013) by the total road length of 108 km. Assuming the disturbance from the access roads also averages 30 m wide (as per the area disturbed for Rte 1856 itself according to the Mende and Astorga GIS file), and that there are 332 km of newly built or repaired access roads, the total area disturbed would be 332,000 x 30 = 9,960,000 m^2. Applying road-bed surface erosion rates derived from the literature (0.01-0.02 m/y), this would imply 99,600 – 199,200 m^3 of new erosion from the access roads. Because these roads extend away from the Río San Juan, their sediment delivery ratio will be much lower than for Rte 1856, which is immediately adjacent to the river. The true sediment delivery ratio is probably around 30% (based on published rates), but assuming a very minimal sediment delivery ratio of 10%, this would imply delivery of 9,960 to 19,920 m^3/yr from the access roads to the Río San Juan.

Total Load Calculation
Adding the sediment delivery from the access roads to the sediment generated directly from the road yields total sediment to the river. To the sediment delivered from Rte 1856 to the river, we add additional sediment from the extensive (but more distant) access roads, 9,960 – 19,920 m^3/yr, resulting in a range of 116,000-150,000 m^3 of total sediment reaching the Río San Juan from Rte 1856 and its access roads.

Checking Results with A Rough Calculation Using Costa Rica's Areas and Rate
It can be useful to step back and look at larger, more general numbers, which while imprecise, can provide "order-of-magnitude" rates to help assess what are reasonable values. A generalized estimate of erosion for the entire road and its disturbed area can be obtained by taking the total area disturbed by road construction as mapped by Mende and Astorga (2013), which is readily discerned from the GIS layer provided in digital form in response to Nicaragua's request for additional data. Mende and Astorga mapped (in red) the area they identified on aerial imagery as having been affected by road construction, which would include the road itself and the adjacent cut and fill slopes, stream crossing fills, quarries, and pioneered but abandoned road segments. (This red area affected by the road is shown in maps presented in Annex 5 and 6.) The total area of this polygon (read directly from the large GIS layer) is 3,502,180 m^2. This includes the roadbed and adjacent slopes, and when divided by the length of 108 km along the river, reflects an average width of disturbance for the road of just over 30 m.

Keeping the calculation transparently simple, we can multiple the total area disturbed by road construction, 3,502,180 m^2, by an erosion rate. Multiplying the total area by the UCR measured rates of surface erosion of 0.095 m/yr, yields a total erosion rate 332,700 m^3/yr for the entire length of Rte 1856. Using the sediment delivery ratio specified by ICE (2013) of 60%, total sediment reaching the Río San Juan would be 199,620 m^3/yr.

Thus, a broad, general calculation using Costa Rican values of mapped area, erosion rate, and sediment delivery ratio, indicates that about 200,000 m^3/yr of sediment reaches the Río San Juan, a figure much closer to my estimate than to the small number put forward by ICE and Costa Rica's consultants.

8. The Road's Contribution of Sediment to the River is Neither Natural Nor Beneficial.

Costa Rica claims that the current sediment load of the Río San Juan is natural, but as discussed by Dr. Edmund Andrews in his report *An Evaluation of the Methods, Calculations, and Conclusions Provided by Costa Rica Regarding the Yield and Transport of Sediment in the Río San Juan Basin* (July 2014), this is clearly not true because of the elevated erosion and sediment load from the river's tributaries in Costa Rica.

The Counter-Memorial states that "sediment is not a pollutant. Rather, the contribution of sediment to a river such as the San Juan is a natural process, and one which is essential to the life of the River. This process is commonly regarded as beneficial." (Counter-Memorial of Costa Rica, ¶3.4.) On the last point, the beneficial nature of sediment contributions, the Counter-Memorial cites an article I authored in 1997, which is provided as Annex 81 to the Counter-Memorial.

These statements are not correct. While rivers have a natural sediment load, and eliminating this natural sediment load by trapping sediment in an upstream dam can have impacts on the downstream channel (the subject of my 1997 article), it is a different matter when sediment loads are increased as a result of anthropogenic activities. In such cases, sediment is treated as pollution by environmental regulators and international organizations. This is because unnatural sediment contributions to bodies of water can be harmful to water quality, aquatic life, and other receptors.

The contribution of sediment from Rte 1856 to the Río San Juan is not a natural process, because nature did not expose the soils to the elements or move them into loose fill piles and stream crossings, where they are now susceptible to erosion and mass wasting.

It may be useful to distinguish between suspended sediments, which are sediment particles held aloft in the water column by turbulence (sand and finer particles), and coarser bedload sediment, which moves along the river bed by rolling, bouncing, and sliding (gravel and sand). Suspended sediment concentration can be expressed as total suspended solids (TSS), usually determined from the concentration of sediment in a small subsample from a river, or a suspended sediment concentration (SSC), which is determined by measuring all the suspended sediment collected from samples across a river, each sample drawing proportionally from all depths of the water column for a true, representative sample (Gray et al. 2000).

Increased delivery of coarse sediment (gravel, sand) to rivers can cause aggradation of the river channel (a topic discussed in more detail in Section 11, below) and burial of important aquatic habitats (USDA Forest Service 1999, Ziemer and Lisle 1992, Madej and Ozaki 2009). Increased fine sediment (clay, silt, sand) can cause:

- reduced exchange of stream and shallow groundwater by clogging gravel and sand beds;
- burial and loss of aquatic vegetation;
- increased turbidity, reduced light penetration, and consequently, reduced primary productivity, which can have effects up the food chain;
- loss of periphyton (discussed below) and consequent impact on the food chain;
- loss or reduction of macroinvertebrate populations (discussed below);
- infiltration of fine sediments into formerly clean gravel substrate needed by aquatic macroinvertebrates, juvenile fish, and other organisms as habitat;

- clogging and damage to gills of fish from high concentrations of suspended sediment;
- reduced ability of fish to recover from wounds;
- disrupted reproduction in some fish by damaging or smothering eggs and larvae and/or affecting adult fishes' reproductive behavior (e.g., visual mate recognition);
- impaired ability of certain fish to locate food as a result of decreased visibility; and
- alteration of the balance of fish species present in a given location.

(E.g., Wood and Armitage 1997, Yamada and Nakmura 2002, Cederholm et al. 1981, Petts 1984a, Brookes 1986, Van Nieuwenhuyse and Laperriere 1986, Henley et al. 2000, Kemp et al. 2011).

As I discussed in my prior report, the delivery of large volumes of sediment to rivers has been documented to cause significant ecological damage. The scientific literature reports effects from all parts of the globe, including Asia, Europe, Australia, and Latin America, and in a wide range of climates from northern-latitudes to the tropics.

Thorne suggests that since there are no salmon in the Río San Juan, the experience in the Pacific Northwest of the US is not relevant. He states that, "Fish and other aquatic organisms in the Río San Juan do not find high turbidity problematic because they are fully adapted to it" (p.50), but presents no citations to scientific literature to support his assertion.

There are many species of fish besides salmon that are sensitive to unnaturally high sediment inputs, as documented in comprehensive reviews by Kemp et al. (2011) and Henley et al. (2000). What the literature actually demonstrates is that some of the most prevalent fish known to exist in the Río San Juan (as reported in Procuenca 2004 and the EDA, Annex 10), such as Cichlids, members of the family Mugiliidae, and Poecilids, are vulnerable to increases in turbidity and suspended sediment.

Increased turbidity has had important consequences on cichlids, as many use vision to maintain a feeding territory, obtain a mate, or defend offspring. Some cichlid species change their behavior depending on turbidity levels (Gray et al. 2012). For example, it is well documented in the Great Lakes of Africa that turbidity interferes with mate choice, relaxes sexual selection, and blocks mechanisms of reproductive isolation (Seehausen et al. 1997). Similar visually mediated speciation events have been documented in Central American cichlid faunas (Barluenga & Meyer 2004; Geiger et al. 2013). In a non-native cichlid, *Oreochromis niloticus*, elevated turbidity levels caused higher concentrations of lysozyme in blood (a potential indication of stress) (Dominguez et al. 2005). Reduced growth and survivorship have been documented at comparatively higher turbidity levels (Ardjosoediro & Ramnarine 2002). Reduced primary productivity (a consequence of higher turbidity levels) can lead to lower fish yields in ponds with relatively high turbidity (Teichert-Coddington et al. 1992).

Fishes in the family Mugiliidae typically spawn at sea and carry out longitudinal migrations into rivers. Different life stages are adapted to different environmental conditions and change their habitat and dietary requirements as they develop. The proportional abundance adults and juveniles of mountain mullid *Agonostomus monticola* in the Costa Rican Térraba River Basin can be affected by differences in water volume and turbidity levels, with mullids needing well-oxygenated, flowing waters with low turbidity (Cota Ribeiro & Umaña Villalobos 2010).

Poecilids are usually small fishes that typically inhabit nearshore, calm-water habitats among submerged vegetation. Similar to cichlids, many poecilids utilize visual cues for mating and feeding, which can be affected by changes in water turbidity (Campos Valera 2013; Heubel & Schlupp 2006; Hubbs 1999). Many poecilids are visual predators of insects, while others consume plant material and organic matter. Both can be affected by increased water turbidity. Increased turbidity can affect insect-eating species by preventing visual detection of terrestrial or aquatic insects, and changing coloration patterns in some species. Increased turbidity can affect algae-eating species by suppressing algal growth, which is driven by penetration of solar energy (i.e., light) to the bottom of rivers, which in turn can be decreased by increased turbidity in the water column.

Similarly, many species of periphyton and macroinvertebrates are sensitive to sediment (Rios 2014). Indeed, it is the sensitivity of some macroinvertebrates to fine sediment and other forms of pollution that makes them suitable organisms for assessing water quality (as described in the EDA) (Bonada et al. 2006, Resh 2008).

Periphyton is the algae and other micro-organisms attached to rocks and other hard substrates in aquatic environments. Dominated by benthic algae, it is important as part of the base of the food chain (Allan and Castillo 2007), and because many periphyton species are sensitive to sediment and other pollutants, periphyton serves as a useful indicator of water quality.

Macroinvertebrates are organisms visible to the naked eye, without a microscope ("macro") and without backbones ("invertebrates"). Aquatic macroinvertebrates live on rocks on the bottoms of rivers and lakes, and are usually dominated by insects (often juvenile stages) as well as snails, aquatic worms, etc. Benthic macroinvertebrates play important roles in riverine food webs, as well as in nutrient processing. As described in the EDA, "The presence of a diverse and abundant fauna of aquatic macro-invertebrates is important for the river, due to the fact that they provide basic functions to the ecosystem," namely the "recycling of organic materials and nutrient cycles" – important for water quality – and their important place in the food chain, "both for aquatic species such as fish, and for terrestrial species (birds, bats, amphibians, some reptiles, spiders and other insects.)" (EDA, p.109) "Aquatic macroinvertebrates are considered to be appropriate bio-indicators of the quality of water…due to the fact that they are sensitive to the contamination and respond fairly rapidly to changes in the structure of the community…and can be used to estimate biotic indexes" (EDA, pp.87-88).

The heavy loads of suspended sediment have a negative effect on algal and macroinvertebrate communities in the Río San Juan, as evidenced by differences in ecological communities established on deltas on the north bank, at the mouths of streams draining forest preserve in Nicaragua, which are not affected by Rte 1856, contrasted with those established on the south-bank deltas, which are affected by sediment eroded from the road.

As described in the report of Dr. Blanca Rios, *Ecological Impacts of Rte 1856 on the San Juan River* (2014), periphyton biomass was roughly twice as high at the undisturbed north-bank delta sites than at the south-bank sites affected by sediment eroded from the road, with differences statistically significant. Dr. Rios also found that macroinvertebrates had much higher species richness and abundance, and importantly, much higher EPT abundance and richness, on deltas on the north side of the Río San Juan, than on the south-bank deltas impacted by sediment from the road. EPT refers to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which are known to be sensitive to sediment and other pollutants, and thus are important indicators of water quality.

It is worth noting that Costa Rica included an attempt to study macroinvertebrates in its “Environmental Diagnostic” report (Annex 10). As explained in the report by Dr. Rios, that study fell short of international standards. The poorly designed, poorly executed study was seriously flawed in many respects, and its conclusions are not supported by its own data. However, the study correctly recognizes the importance of macroinvertebrates and their utility as bio-indicators (EDA, pp.87-88).

In my report of October 2013, I presented results of an initial study of periphyton and benthic macroinvertebrates sampled from deltas entering the Río San Juan from both north and south banks. In commenting on these results, Professor Thorne said, “What we are not told is whether those sites were on any of the multiple deltas observed at the Nicaraguan side of the River earlier that month. If they were then it would be fair to compare them” (Annex 9, ¶82). Building upon the results of this initial sampling, Dr. Blanca Rios conducted an expanded sampling program, with eight sites on each river bank in March-May 2014, whose results she presents in her report.

Professor Thorne’s unsupported assertion that “Fish and other aquatic organisms in the Río San Juan do not find high turbidity problematic because they are fully adapted to it” is not only inconsistent with the literature on the species of fish and macroinvertebrates known to exist in the San Juan River, but also inconsistent with recent aquatic ecology sampling in the San Juan River itself.

9. Costa Rica’s Experts Compare the Road’s Contributions to Unreliable Total Load Figures.

When Professor Thorne says that the contribution of sediment from the Road is insignificant, he is not comparing that contribution to a figure that accurately represents the sediment load of the Río San Juan. Various problems in his approach are laid out in the report by Dr. Andrews.

Professor Thorne adopts the estimate made by ICE (Annex 4) that the total sediment load of the Río San Juan in 2010-2013, after construction of Rte 1856, was 9,133,000 tons/yr. This estimate is the sum of estimates of suspended sediment load and bedload. Thus, any error in either component estimate leads to an erroneous total load estimate.

There are many problems with the total load values presented in the ICE Report, which the report of Dr. Andrews discusses in detail, including that the estimate rests on data that is unrepresentative and unreliable. Even if it were based on reliable data, however, the figure Professor Thorne adopts overestimates the sediment load of the Río San Juan during the time period in question, because of an error in the bedload calculation.

When estimating bedload, river slope is an important factor. Slope is defined as the drop in elevation over the distance. The steeper the slope, the greater the energy available to erode and transport sediment. Using an exaggerated slope when calculating bedload transport produces a larger bedload transport value. The estimate on which Professor Thorne relies, from the ICE Report (Annex 4), however, assumes a slope value that is too high. This leads to an exaggerated bedload estimate of 2,559,000 tons/yr. As Dr. Andrews explains, when the exaggerated slope value is corrected (and assuming the other ICE inputs are accurate), the true bedload is less than 1/7 of Professor Thorne's estimate.[9] Because bedload is a component of total sediment load, the error in ICE's bedload calculation – which Professor Thorne repeats – leads to a total sediment estimate that is approximately 30% too high. Drs. Mende and Astorga make the same mistake in Annex 5 to the Counter-Memorial, where they compare estimates of sediment input from various road-related features to what they assume, based on the ICE Report, is the River's sediment load. (p.2) The ICE bedload calculations form part of the total sediment load against which they compare the contributions of the input locations I identified. The errors in the bedload calculation mean that they understate the relative contribution of the Road to the sediment load in the Río San Juan.

One additional point about slope values is relevant here. River slope is defined as the drop in elevation over the distance. The Río San Juan drops from an elevation of 32.7 m at Lake Nicaragua to sea level over a distance of approximately 190 km. Thus, its average slope is 32.7 m divided by 190,000 m, or approximately 0.000172.

As discussed above, Professor Thorne relies on bedload calculations that incorporate ICE's erroneous slope values. In his Table 1, however, he lists reaches of the river with their drop and distance, as well as his own calculation of their slopes. He greatly exaggerates the slopes, asserting that the Río San Juan has a slope of 1 percent or just under in some reaches. Experienced geomorphologists would recognize 1 percent as an extremely high slope for a large river. Professor Thorne's slope values are overstated by factors of about 55 to 58, as illustrated in Table C. The implications of this error are significant, in that channel slope is a fundamental variable of rivers, which affects many river process, including bedload transport, whose calculation can be distorted by use of erroneously large slope values.

Table C. Slopes for Reaches of the Río San Juan, as claimed by Thorne, and corrected values.

Reach*	Length* (km)	Fall in Elevation* (m)	Thorne's Slope* (m/m)	Correct slope calculation (m/m)	Correct slope (m/m)	Thorne's error
Rio Frio – Rio Pocosol	52.86	6.5	0.007	6.5/52,860 =	0.000123	56.9 times too high
Rio Pocosol – Rio San Carlos	52.67	7.7	0.008	7.7/52,670 =	0.000146	54.8 times too high
Rio San Carlos – Rio Sarapiqui	39.86	6.9	0.010	6.9/39,860 =	0.000173	57.8 times too high
Rio Sarapiqui – Delta	22.04	3.8	0.010	3.8/22,040 =	0.000172	58.1 times too high
Delta – Caribbean Sea	32.35	5	0.009	5/32,350 =	0.000154	58.4 times too high

* Reaches, length, fall, and Thorne's slope taken from Thorne's Table 1.

[9] Dr. Andrews corrected ICE's estimate of bedload at the Delta Colorado gage. Applying the incorrect slope value, ICE estimates the bedload to be 2,488,000 tons/yr. Applying a correct slope, Dr. Andrews estimated the bedload there to be 330,000 tons/yr. The ICE report's erroneous calculation at the Delta Colorado gage makes up the bulk of its bedload estimate for the mainstem Río San Juan.

10. The Río San Juan's High Sediment Load

Thorne asserts that the high levels of sediment in the Río San Juan are natural. This is not true. The actual natural sediment load of the Río San Juan would have been significantly smaller prior to extensive deforestation and land use in Costa Rica.

As shown in the report of Dr. Andrews, the median natural sediment yield of undisturbed tropical rain forest is approximately1/50th the amount reported by Professor Thorne for the Río San Juan. Natural sediment yields of more than 1/20th the amount reported by Professor Thorne are rare. There is some variability in natural yields, but not to the extent that would approach Professor Thorne's estimate of the current sediment load of the Río San Juan, which is much higher than would be expected from a forested landscape in this region. The explanation is the uncontrolled deforestation and land conversion on highly erodible soils in the Costa Rican basins of the Rio San Carlos and Rio Sarapiqui.

Dr. Andrews presents the evidence and literature regarding the land use that has resulted in such an unnaturally elevated load in the Río San Juan. The EDA (Annex 10) also lays out extensive evidence regarding this widespread deforestation in Costa Rica (e.g., pp.39, 45, 46, 58, 66).

Given that the pre-deforestation sediment yield of the Río San Juan was probably 1/20th to 1/50th of the current yield, the sediment yield from Rte 1856 constitutes a much larger percentage of the river's *natural* sediment load.

11. Morphological Impacts of Rte 1856

Costa Rica argues that sediment eroded from Rte 1856 would amount to the equivalent of a "single grain of sand" if deposited in the Delta of the Río San Juan. While perhaps a visually compelling image, this argument is a significant distortion and is fallacious on two important counts.

Costa Rica cites an amount of sediment eroded from Rte 1856 as though this was the amount that differed from natural background rates, ignoring the much-larger volume of sediment eroded from deforested Costa Rican tributaries of the Río San Juan. Deforestation and poor land use have increased sediment yield from the Costa Rican tributaries 20 to 50 times over natural background levels (Andrews 2014: Section IV(A)). The combination of both the road-derived sediment and unnaturally increased sediment yield from these Costa Rican tributaries is the true difference from natural conditions and is thus the relevant comparison to make.

Second, the "single grain of sand" image implies that sediment would be spread evenly over the bed, which would be geomorphically implausible and unrealistic. As sediment is transported through a river system, some will continue downstream into the coastal zone. Of the sediment that is deposited in the river channel, most of it will build up (or 'aggrade') on discrete bars, which can occur in the middle of the channel or along the margins, depending on local hydraulic conditions and other factors.

Another likely place for sediment deposition is in areas of low velocity, such as along the river bank and where velocities are slowed by islands or other features. As sediments deposit (or ‘accrete’) along the edges of islands and/or the river bank, they can fill in the river in between the island and bank, causing the two features to join as a result of unnaturally-increased sediment loads.

River deltas are sites of natural sediment deposition, where the slope of the river declines and rivers splits into two or more ‘distributary’ channels. The delta landform owes itself to deposition. An increase in the amount of sediment delivered to the head of a delta can cause one or more distributary channels to clog with sediment, changing the flow split and altering the morphology of the river.

Along the Río San Juan, another type of delta is visible: These are the deltas that develop when steeper tributary streams enter the mainstem. Analogous to the slowing of the main river flow when it enters the sea, the streams slow down as they enter the river, and deposit their sediments. The coarse sediments (gravel and sand) deposit first, building up the tributary delta landforms. These deltas occur at the confluences of the small and medium-sized tributaries, whose flow is sufficient to carry the sediment down the steeply sloping tributary stream channel, but which deposit their sediment as they enter the main Río San Juan. (Large tributaries such as the Rio San Carlos and Rio Sarapiqui do not form deltas because their flows are more comparable to those of the mainstem Río San Juan, and their sediment loads are much greater. Downstream of Boca San Carlos, the Río San Juan has more frequent sand bars, islands, and shallow areas.) Along the south bank of the Río San Juan there are multiple deltas that have built up from the large quantities of sediment eroded from Rte 1856. Some are pre-existing deltas of natural streams on which road-derived sediment has deposited, while some are completely new features built of sediment eroded from the road and now extending into the Río San Juan from the south bank. Deltas of sediment eroded from the road can be clearly seen in oblique aerial images, such as Figure 10b, which shows the delta built from sediments eroded from a stream crossing fill 18 km downstream of Mojon II (at SES 9.4).

Examples of deltas built of road-derived sediment are presented in Appendix F. First a diagram showing in plan view (looking south) and section view (looking upstream) how deltas form in the mainstem Río San Juan from sediment transported from a source such as the eroding Rte 1856. Next the delta of SES 9.6 (18.2 km downstream of Mojon II) is documented through photographs and field measurements of dimensions. When measured on 30 March 2014, this delta was approximately 21 m long (parallel to the river), 15 m wide (normal to the river), and 2 m above the river water surface. Next is photodocumentation of the delta for 9.5 (similar dimensions to 9.6). The delta of SES 9.4 is similar in form to the other two, but more elongate in shape, being 25 m long, 10 m wide, and 1.8 m high above the current water surface. SES 8.1 and 8.2 also produced deltas, but smaller. At SES 9.7, another, less elongated delta formed, with dimensions of 25 m long, 21 m long, and 1.7 m high. Also near SES 9.7 is an additional delta, with dimensions 30 m long, 13 m wide, and 1.6 m above the water surface. Finally, Caño Venado is a natural stream, but its delta has received a large sediment load from Rte 1856, and the distinctive red-colored sediment from the road can be seen making up most of the delta form.

The fact that sediment from Rte 1856 has been permitted to enter the Río San Juan in sufficient quantities to create large, visible deltas reflects the lack of planning for the project, the lack of even basic environmental safeguards and sound construction practices, and the lack of effective erosion control and slope stabilization. This does not constitute acceptable practice in any way.

In his *Report on the Risk of Irreversible Harm to the Río San Juan Relating to the Construction of the Border Road in Costa Rica* (November 2013), Annex 9 to the Counter-Memorial, Professor Thorne pointed out that deltas exist along the north bank of the river as well as the south bank, and argued that some of the north-bank deltas are larger than deltas on the south bank, implying that this cast doubt on the road-derived sediment origin of much of the sediment in the deltas along the south bank. In his December 2013 report, Thorne repeated this claim, and presented oblique aerial images from my 2012 report and belittled the size of the deltas appearing in the photographs, referring to the "small dimensions and morphological insignificance" compared to the deltas he photographed at unspecified locations and on an unspecified date in May 2013 (p.95, vol.I:241). Professor Thorne, however, did not acknowledge that a delta will appear much larger at low river level than at high river level, because when the river is high, more of the delta is under water and thus invisible. It is misleading to compare deltas as they appeared in the photographs in my 2012 report, which were taken on 18 October 2012 at higher flows, with deltas appearing in his photographs taken on an unspecified date in May 2013 at much lower flows. Although continuous flow measurements for 2012 and 2013 are lacking, estimated average flows are 498 m^3s^{-1} at El Castillo and 1434 m^3s^{-1} below the confluence of Rio Sarapiqui for October, compared to only 235 m^3s^{-1} at El Castillo and 791 m^3s^{-1} below Rio Sarapiqui in May (OAS 1997). Thus, the flows in October would have been roughly twice those in May, so deltas shown in my photographs of October 2012 would have been largely under water, compared to deltas photographed in May 2013.

Professor Thorne makes much of the existence of deltas on the Nicaraguan side of the river, and presents 13 photographs of deltas, which he states were on the north bank of the Río San Juan (but for which Costa Rica could not provide coordinates or even "approximate locations"). There are a number of tributaries draining the Nicaraguan forest preserve on the north side of the Río San Juan, and there are natural deltas at the mouths of some of these streams. The existence of natural deltas on the north bank of the river does not change the fact that many of the deltas on the south bank are either natural deltas that are now severely impacted or dominated by unnaturally high sediment loads from the eroding Rte 1856, and in some cases are new deltas built from very high sediment loads from the road, not associated with large streams. In many oblique aerial photographs, it is possible to see clearly that sediment in the deltas is derived from erosion of the road, such as Figures 10b and 15b.

These deltas are distinct from natural deltas in that they are made up of largely of reddish-colored sediment eroded from deeply-weathered bedrock material moved for road construction (or now eroding from exposed cutslopes). This sediment is reddish in color and is easily-crumbled (what we have previously referred to as "angular, friable clasts"), reflecting the deeply-weathered hillslope from which the sediment recently came. These clasts are distinct from the more rounded, competent gravels that one typically encounters in a natural stream, and which dominate the deltas on the northern bank of the River.

Professor Thorne suggests that the newly created deltas built of sediment eroded from the road provide "fresh habitats and open niches for pioneer plant species" (Thorne, ¶9.9.). However, these deltas are formed by a "lag deposit" of coarser sediments (gravels, sand), i.e., the heavier fraction of the sediment load deposited when the sediment-laden stream flows into the river. Once the delta has built up, there will be a channel whose slope allows it to carry coarse sediment from the river bank out into the main channel with its deeper waters and higher currents. Typically this coarser sediment in the delta would be at most a few percent of the total sediment load passing this point. The unnaturally elevated suspended sediment load passing over the delta affects the benthic community, as reflected in the results of the ecological study conducted by Dr Blanca Rios, discussed above. Thus, while the new deltas provide substrate for periphyton (algae and other organisms growing on the surfaces of gravel and rock) and macro-invertebrates, they are also subject to unnaturally high and deleterious suspended sediment loads, which result in communities of algae and macroinvertebrates that reflect deteriorated water quality conditions.

12. Risks of Larger Contributions from Rte 1856.

Professor Thorne asserts that I have "acknowledge[d] that relatively little erosion and sediment delivery has occurred to date" but does not provide a specific paragraph or page number to support his assertion (¶4.5; repeated from Annex 9, p.16). It is not, and has never been, my position that there has been "little" erosion to date. The volume of sediment delivered to date to the Río San Juan is substantial, and is small only *relative* to the much larger input that can be expected during intense rains that accompany tropical storms, hurricanes, and other such events, which could trigger landslides from destabilized cut slopes and fill piles, as documented elsewhere in the scientific literature (e.g., Larsen and Parks 1997, Larsen and Roman 2001, Glide 2003).

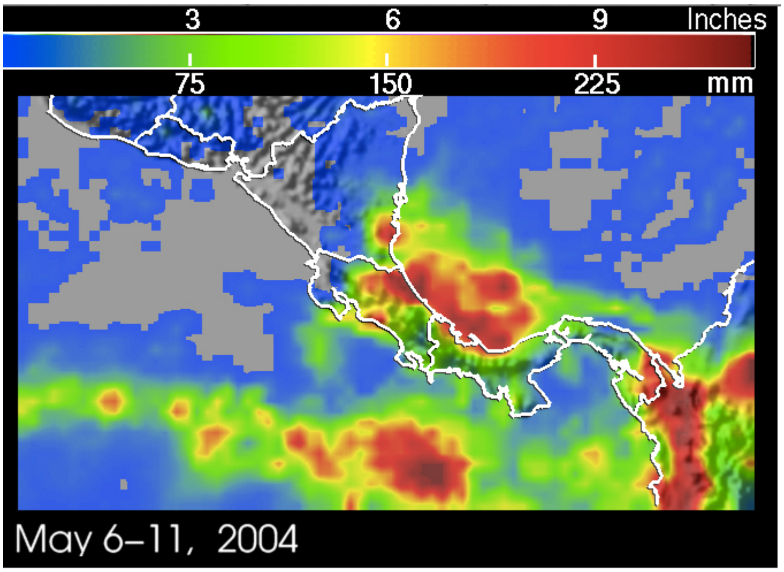
Hurricanes and Tropical Storms

Professor Thorne disputes my prediction of greater erosion rates during intense rains from future storms, by claiming that hurricanes do not strike the area and that a hurricane or tropical storm striking the RSJ "would actually be unprecedented and it is therefore highly unlikely" (Thorne, ¶6.20). However, it is not true that a hurricane or tropical storm has never struck the Río San Juan. The eyes of Hurricanes Irene and Olivia in 1971 both tracked just to the north of the Río San Juan. Tropical storms, which can produce intense rains sufficient to trigger landslides, are well-documented in the region as well.

Professor Thorne states that the website of the US National Oceanographic and Atmospheric Administration (NOAA) has "no record of Costa Rica ever having been struck by a hurricane or tropical storm," based on a map from the NOAA website reproduced at ¶6.20 of Professor Thorne's report. This claim that Costa Rica has never been struck by a hurricane is not the same thing as the Río San Juan never having been hit by a hurricane or tropical storm. In any event, Professor Thorne himself previously stated that the Costa Rican catchments that supply water and sediment to the Río San Juan "are subject to extreme events including…hurricanes" (2011 Thorne, p.vi).

An example of the heavy rains that can occur over the Río San Juan and its Costa Rican tributary basins is the tropical storm that occurred 6-11 May 2004 that produced rains in excess of 200 mm over an area of approximately 400 x 200 km, with intense rains mapped throughout the basins of the Costa Rican tributaries to the Río San Juan (e.g., Rio San Carlos, Rio Sarapiqui) (Figure 32). Over 2000 people were forced to evacuate and one person died in the flooding (NASA 2014).

Figure 32. Heavy rains associated with a tropical easterly wave, 6-11 May 2004. Source: US National Aeronautics and Space Administration (NASA), available online at http://eoimages.gsfc.nasa.gov/images/imagerecords/13000/13158/CostaRica_TRMM2004132_lrg.jpg, last accessed July 2014.



The tracks of hurricane eyes presented on the NOAA map reproduced by Professor Thorne do not depict the extent of the areas affected by the hurricanes the paths of which are being tracked. The area affected by a hurricane is, inevitably, much wider than the track of the eye, and is typically at least 200 km wide. The eye of Hurricane Mitch in 1998 passed through Honduras and Guatemala, some 300 km to the north of the Río San Juan, yet seven people were killed by flooding in Costa Rica, mostly in the northeast, and thousands were forced from their homes (NOAA 1999).

I made this point in my November 2013 *Comments on Costa Rican Submissions* (pp.5, 11), in response to Professor Thorne's argument in Annex 9. Although he has repeated his erroneous and misleading statements on the issue of hurricanes in his newest report, he has also added a response to my criticism. He now acknowledges that "Costa Rica has been affected in the past by hurricanes passing to the north of the country," identifying Hurricanes Joan, Mitch, and Stan, but he argues that the rainfall from those hurricanes in the Río San Juan basin "were in each event unexceptional and unlikely to cause widespread destruction because the basin of the Río San Juan receives abundant rainfall in most years and the hydrology, sediment dynamics, morphology and environment of the River are fully adjusted to the effects of frequent and heavy rainstorms" (Thorne, ¶6.20).

Professor Thorne, however, is mistaken to suggest that the rainfall levels reported in Costa Rica during Hurricanes Joan, Mitch, and Stan were "unexceptional." He relies upon a letter from the General Director of the Costa Rican National Meteorological Institute (Annex 68 to Costa Rica's Counter-Memorial) for details regarding the rainfalls recorded in Costa Rica during each of these storms. According to this letter, the most recent of the three storms, Hurricane Stan, affected Costa Rica from October 2 to October 5, 2005, delivering during that 4-day period rainfall measuring anywhere from 15 mm (on the Caribbean coast) to 150 mm in the Sarapiqui area. 150 mm over 4 days – for an average of 37.5 mm/day – is a substantial amount of rain. The levels reported in Annex 68 for Hurricane Joan are even higher: 20-250 mm from October 20-23, 1998. The daily average for that 4-day period was somewhere between 5 and 62.5 mm per day. These are, by any definition, substantial amounts and were sufficient to cause flooding that killed seven people and caused thousands to flee their homes in northeast Costa Rica (NOAA 1999).

Professor Thorne is also incorrect to claim that rainfall like that received during the hurricanes reported to date is "unlikely to cause widespread destruction because the basin of the Río San Juan receives abundant rainfall in most years and the hydrology, sediment dynamics, morphology and environment of the River are fully adjusted to the effects of frequent and heavy rainstorms" (Thorne, ¶6.20). Whether or not the River is "fully adjusted" to the effects of frequent and heavy rainstorms, there can be no argument that the River and its environment are fully adjusted to the impacts such levels of rain would have now that Rte 1856 exists. As of May 2014, no such rains had yet hit the road and its unstable, uncovered cuts and fills, which had already experienced widespread erosion and stream crossing failure even in the past few relatively dry years.

Professor Thorne also asserts that if a hurricane did "strike the basin directly, there would likely be damage on a massive scale, including flooding and landslides affecting the entire region. In such a case, damage would be severe and extensive whether or not the Road existed" (Thorne, ¶6.21). In effect, he says everything will be so bad we won't notice the added landsliding caused by the road.

It may be the case that damage caused by a hurricane "would be severe and extensive whether or not the Road existed," but the areas disturbed by Rte 1856 are at serious risk of experiencing far greater landslide impacts than undisturbed forest. The scientific literature is clear on this point: areas disturbed by road construction and other such land disturbance have more severe erosion and landsliding than undisturbed sites during intense rains, as reviewed below.

While most natural slopes will hold together during the intense rains of a hurricane, hillsides altered by cut and fill road construction are highly vulnerable to failure both of the oversteepened cutslope with its emerging groundwater, and the precariously perched fillslopes. Many studies have shown greater hurricane or monsoon damage on landscapes disturbed by road construction and deforestation than on natural slopes. For instance, studies in New Zealand (reviewed by Glade 2003) have demonstrated that human-disturbed slopes (from forest clearance, road construction, etc.) are vastly more vulnerable to landsliding than native bush or even reforested slopes (e.g., Parkner et al. 2006). One of the best documented illustrations of the effect of land clearance on vulnerability to erosion was the effect of tropical cyclone Bola on the East Cape of the North Island of New Zealand in 1988, where landslides were many times more intense and widespread on human-disturbed areas than native bush or afforested areas (Hicks 1991, Kansai et al. 2005). In Jamaica, Maharaj (1993) documented a strong association between rainfall-driven landslides and disturbance by a road, as did Douglas (1967) and Tan (1984) in Malaysia, and Larsen and Parks (1997) and Larsen and Roman (2001) in Puerto Rico.

We can expect that intense rains will occur, and that when they do, the areas destabilized by the road will experience far higher frequency and severity of landslides than areas not affected by the road construction, other factors being the same. If the massive fill piles along Rte 1856 (such as those documented at Severely Eroding Sites 9.4, 9.5, 9.6, and elsewhere) are not removed and the cutslope stabilized, there is a substantial risk of sudden, massive transfers of sediment into the Río San Juan during intense rains.

Earthquakes

Clearing and earth moving for road construction causes previously stable slopes to be destabilized, by removing vegetation cover, breaking up soil structure, and increasing slope steepness. Moreover, once the vegetation dies, deep roots begin to decay (which typically occurs over a couple of years), which further destabilizes the slope through the loss of root strength. Weakened slopes are subject to much greater frequency of landsliding than native slopes. One important 'trigger' for landslides is intense rain, which saturates the slopes and reduces the frictional hold between grains in the slope, allowing landslides to move. Another important 'trigger' is shaking during earthquakes, which can detach the landslide mass, causing it to move.

Earthquakes constitute an important potential trigger for landslides along the Río San Juan. The region is seismically active, as acknowledged by Professor Thorne at various points in his 2011 report (e.g., pp.vi, II-9, Thorne 2011), who states that Costa Rican catchments which supply water and sediment to the Río San Juan "are subject to extreme events including…earthquakes" (Thorne 2011, p.vi).

The fact that earthquakes occur frequently in the region is reflected in Annex 2 of the Costa Rican Counter Memorial, which noted (p.14): "Some sites and dates [for planting events] were changed due to force majeure events. For example, the bridge over Río Sucio fell due to the Sámara earthquake. Consequently, the events programmed for Costa Rican Delta and Trinidad had to be changed; they were performed at the mouth of San Carlos River."

The EDA (Annex 10, p.33) noted, "in 2012 and after the Sámara Earthquake of September 5, 2012, 9 earth tremors were recorded along the Colorado River, close to the Nicaraguan border, with magnitudes (Mw) of 3.1 up to 3.9 (Barquero 2013) The alignment of the epicenters of such seismic activity coincide with the Colorado River, with a northwestern to southeastern orientation, which suggests the presence of an active fault. This recent sismic [sic] activity could accelerate exogenous processes and increase the sedimentation rate towards the San Juan River."

13. Concluding Remarks

The attempts to construct Rte 1856 along the south bank of the Río San Juan have destabilized hillslopes adjacent to the river, and delivered large quantities of sediment to the Río San Juan, impacting the riverine environment. The construction project was characterized by lack of planning, lack of environmental analysis, and poor construction practices. By international environmental standards, the destabilization of the landscape by construction of Rte 1856 and the resulting erosion and sediment delivery to the Río San Juan would be considered an unacceptable impact.

Costa Rica argues that the sediment eroded from the road is only a small fraction of the total load of the river. In addition to other problems documented above, this argument leaves out a critically important point: that the sediment load of the Río San Juan is dominated by sediments eroded from deforestation and continuing, uncontrolled disturbance of erodible volcanic soils within Costa Rica, principally in the basins of the Rio San Carlos and Rio Sarapiqui. Moreover, Costa Rica has overestimated the river's bedload transport, through fundamental errors and biases in calculations and estimates (Andrews 2014). More significantly, it has underestimated erosion from the road by selecting monitoring sites that avoided severely eroding and unstable sections of Rte 1856, and by under-reporting the dimensions of severely eroding sites. In short, Costa Rica has submitted reports purporting to show that the road has had no appreciable impact on the Río San Juan. Upon close inspection, however, it becomes apparent that these reports contain fundamental errors and, as a result, cannot be considered credible scientific evidence.

The reports submitted by Costa Rica also imply that conditions have improved along Rte 1856. However, erosion has visibly worsened since I first observed Rte 1856 in October 2012. The progression of erosion and the delivery of large quantities of sediment to the Río San Juan are clear in sequences of aerial (helicopter) photographs and cloud-free satellite imagery that has become available.

In its current condition, Rte 1856 is not complete and cannot be driven except for short sections, and even those sections pose safety problems. There is a significant danger posed to the Río San Juan from petroleum, chemical fertilizers, herbicides, and pesticides that could be spilled from trucks due to the failure of fillslopes or stream crossings (which is already occurring, and which would be only more likely after heavy rains and under the load of heavy trucks), or as a result of the road's overly steep grades and excessively sharp turns. The problems with unsafe and unstable slopes and poor stream crossings are compounded by the extreme proximity to the Río San Juan of most of Rte 1856.

To reduce the hazard posed by Rte 1856, the entire existing road would need to be inspected and objectively analyzed by qualified road engineers. In some sections, such as those on steep slopes adjacent to the river bank, the road should be moved inland to less inherently risky routes, and the damaged portions of the landscape repaired by stabilizing the cutslopes and hauling away fill material to minimize future sediment delivery to the Río San Juan. Other parts of the road can probably be stabilized in the current alignment or with minor realignments, but serious measures are necessary to stabilize and protect these sections as well.

Appendices

A. Inventory of Severely Eroding Sites
B. Letter from Jeff Campbell of Spatial Solutions, Inc. (28 May 2014)
C. Map of Potentially Unsafe Stream Crossings
D. Map of Potentially Unsafe Slopes
E. Map of Sections of Rte 1856 where Relocation Should be Considered
F. Road-Derived Deltas in the Río San Juan
G. Roy Sidle et al., *Unprecedented rates of landslide and surface erosion along a newly constructed road in Yunnan, China*, 57 Nat. Hazards 313 (2011)

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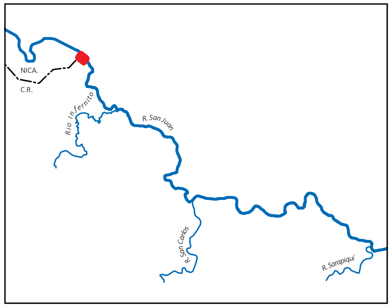
Appendix A

Inventory of Severely Eroding Sites

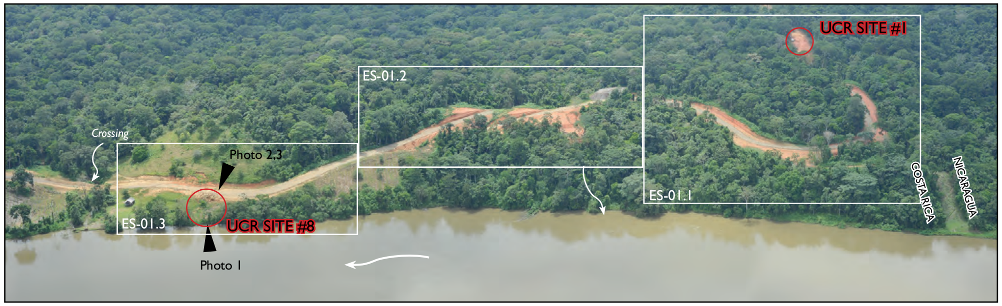
Severe Eroding Area 01a

RKM 0.0 to 1.1



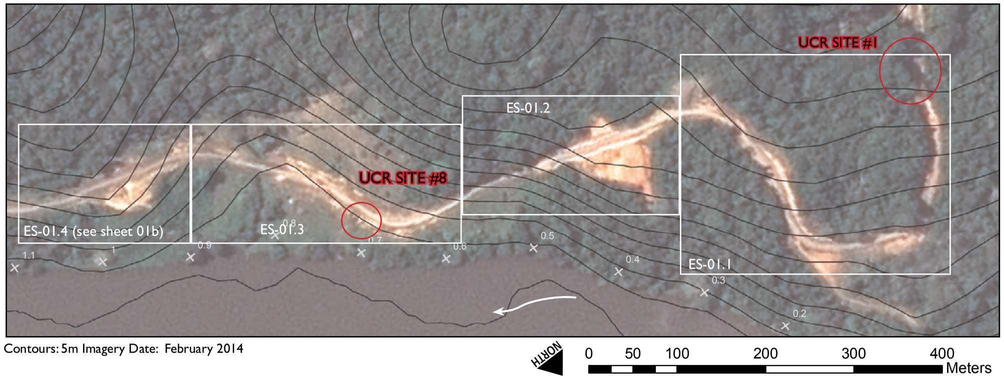
Extent Map

Photo 1. Road fill landslide eroding directly into the river (from boat, May 2012).



Photos taken from helicopter, October 2012.

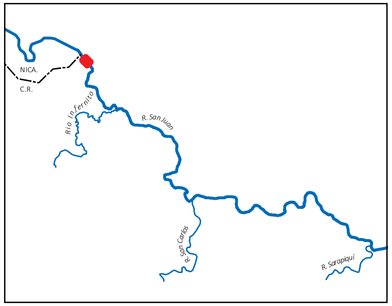
Photo 2,3. Failure and gullying of road fill prism with direct delivery to river (from Annex 5, Mende et al. 2013).



Contours: 5m Imagery Date: February 2014

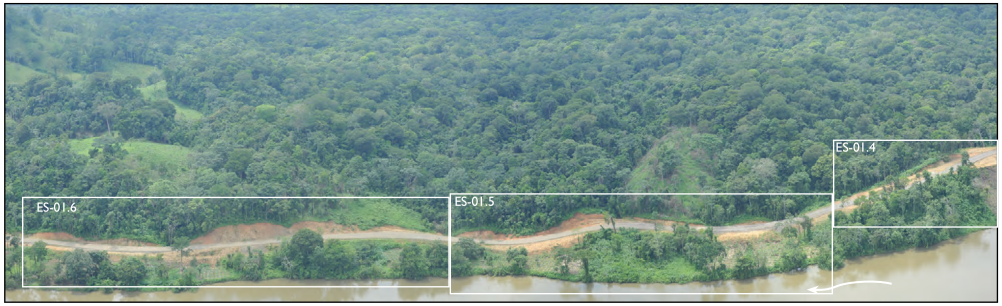
Severe Eroding Area 01b

RKM 1.1 to 2



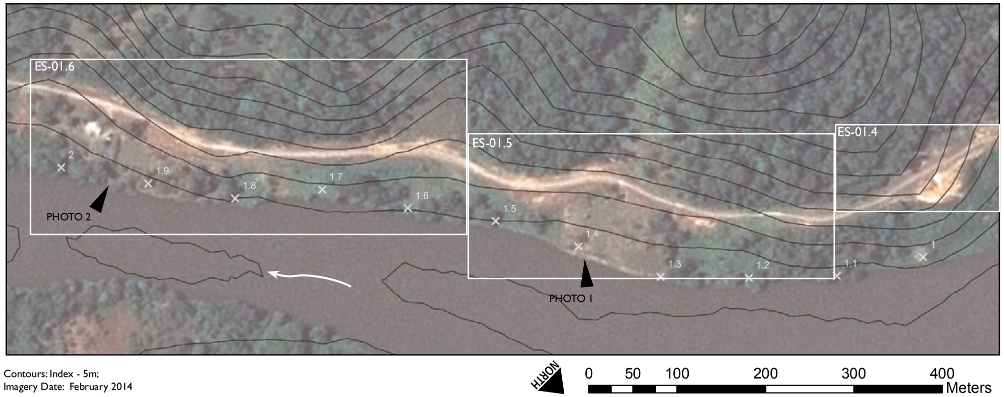
Extent Map

Photo 1. Eroding slope of sidecast fill material and failing erosion control measures (from boat, March 2014).



Panoramic view from helicopter, October 2012.

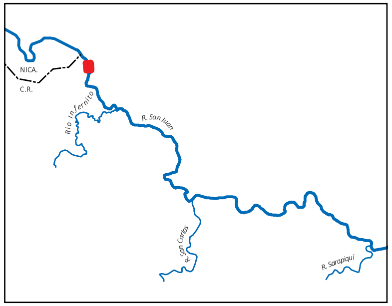
Photo 2. Steep eroding cut and fill slope in ES-01.5. (from helicopter, October 2012).



Contours: Index - 5m;
Imagery Date: February 2014

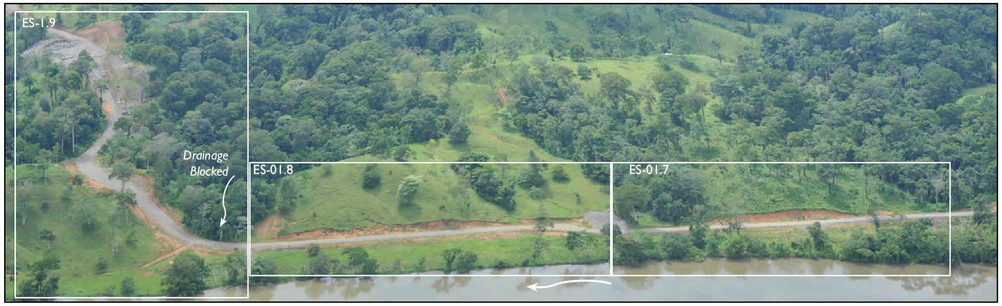
Severe Eroding Area 01c

RKM 2.0 to 2.6



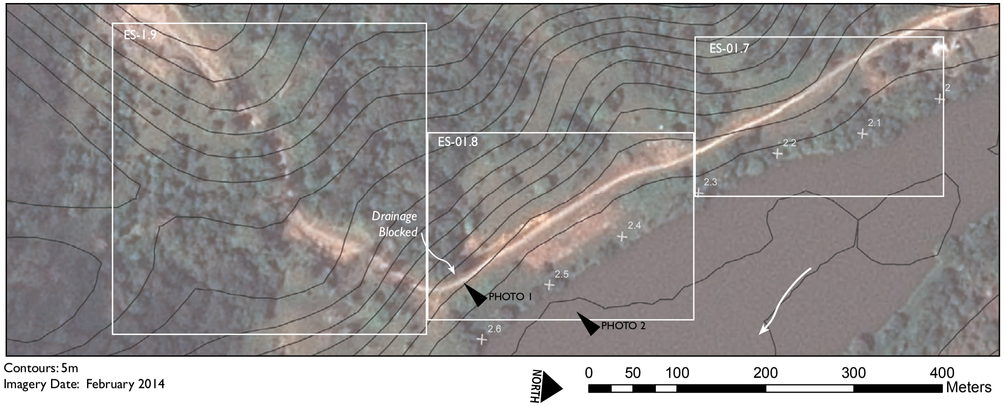
Extent Map

Photo 1. Collapsed road fill sink hole at blocked drainage (from Annex 5, Mende et al. 2013).



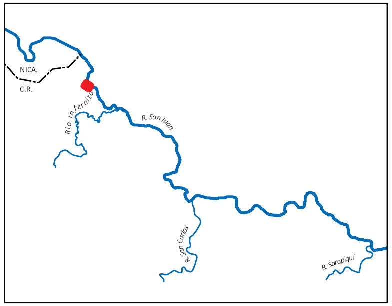
Panoramic view from helicopter, October 2012.

Eroding cut slope (view from helicopter, October 2013.)



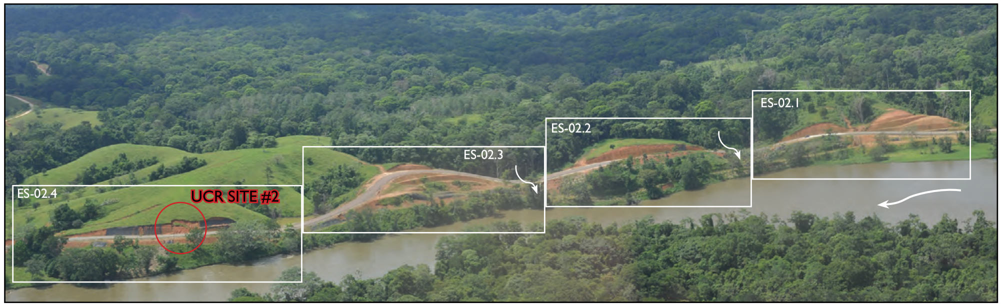
Contours: 5m
Imagery Date: February 2014

Severe Eroding Area 02
RKM 6.0 to 6.9



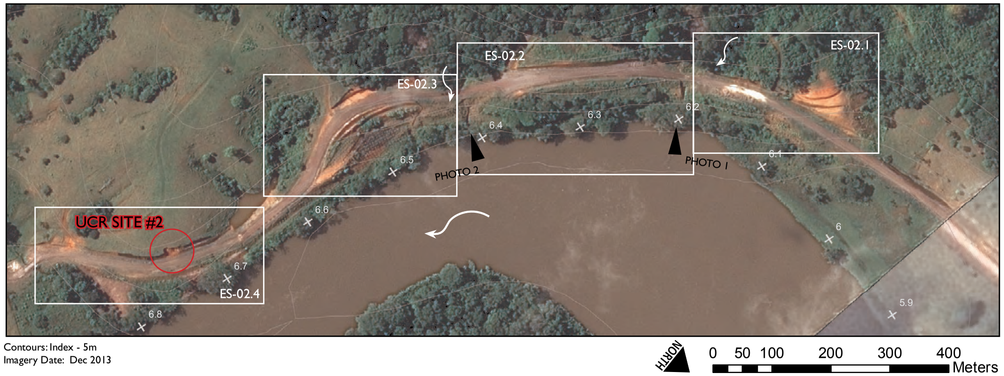
Extent Map

Photo 1. Gullying fill slope and failing erosion control fabric. View from riverboat, October 2012.



Panoramic view from helicopter, October 2012.

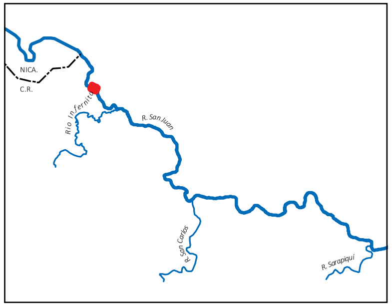
Photo 2. Gullying hillslope with direct inputs to Rio San Juan. View from riverboat October 2012.



Contours: Index - 5m
Imagery Date: Dec 2013

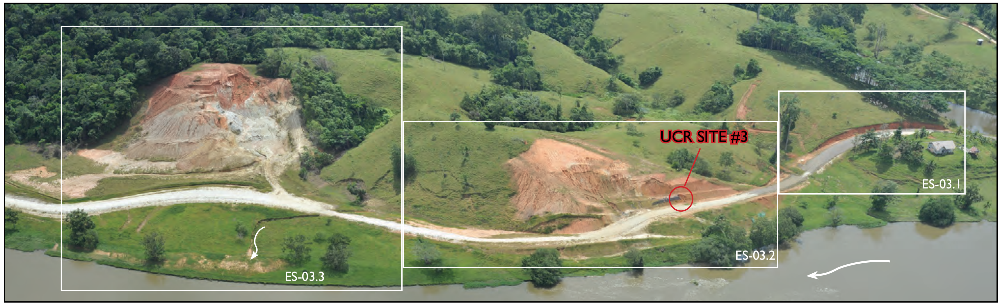
Severe Eroding Area 03

RKM 7.1 to 7.9



Extent Map

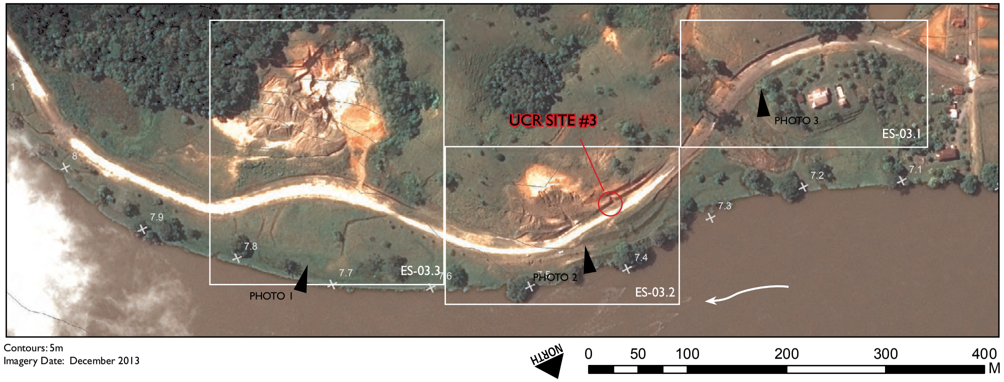
Photo 2. Gullying borrow area / cutslope and denuded hillside (view from riverboat, October 2013).



Panoramic view from helicopter, October 2012.

Photo 1. Eroding quarry site adjacent to the road (view from riverboat, October 2013).

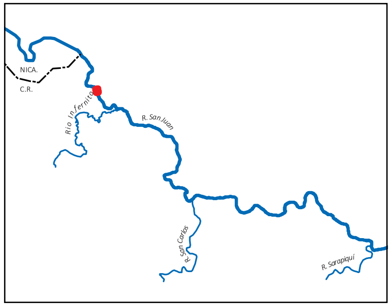
Photo 3. Eroding cutslope adjacent to blocked drainage (view from riverboat, October 2013).



Contours: 5m
Imagery Date: December 2013

Severe Eroding Area 04

RKM 8.0 to 8.7



Extent Map

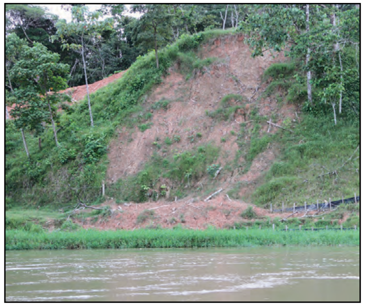
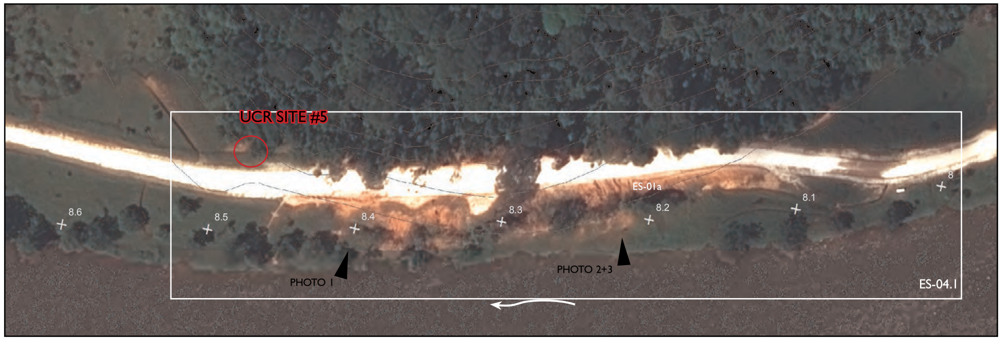


Photo 1. Steep eroding slope of sidecast fill material, and deposits along toe of slope. (view from riverboat, October 2013).

Panoramic view from helicopter, October 2012.

Photo 2. Steep eroding slope of sidecast fill material, and deposits along toe of slope. (view from riverboat, October 2012).

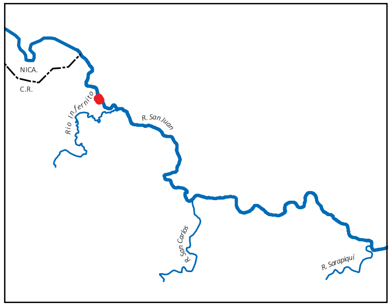
Photo 3. Steep eroding slope of sidecast fill material, overwhelmed silt fences, and deposits along toe of slope. (view from riverboat, March 2013).



Contours: Index - 5m
Imagery Date: November 2012

Severe Eroding Area 05

RKM 9.3 to 9.9

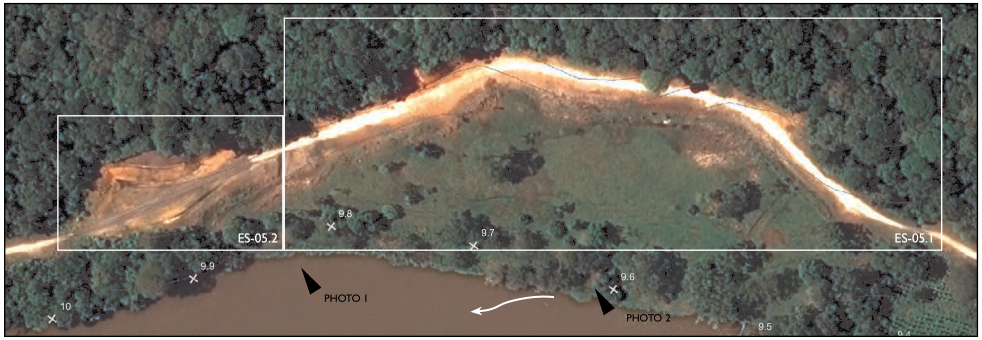


Extent Map

Photo 1. Eroding road cuts and fill slope in close proximity to the river (view from riverboat, May 2013).

Panoramic view from helicopter, October 2012.

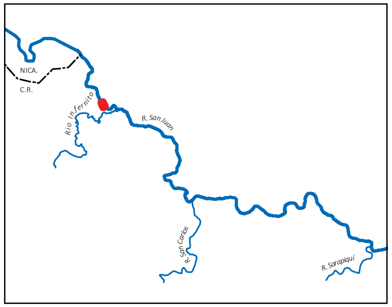
Photo 2. Eroding road cuts and fill slope in close proximity to the river (view from riverboat, March 2014).



Contours: Index - 5m
Imagery Date: December 2013

Severe Eroding Area 06a

RKM 10.4 to 11.3



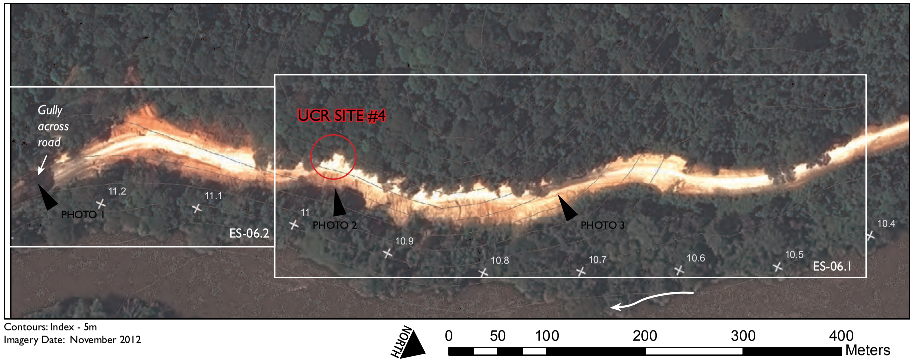
Extent Map

Photo 2. Steep cut and fill slopes (view from helicopter, October 2013)

Panoramic view from helicopter, October 2012.

Photo 1. Gully across road (from Mende & Astorga 2013, p36)

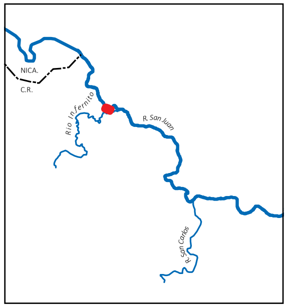
Photo 3. Rills on cut slope (from Mende & Astorga 2013, p36)



Contours: Index - 5m
Imagery Date: November 2012

Severe Eroding Area 06b

RKM 11.3 to 12.2

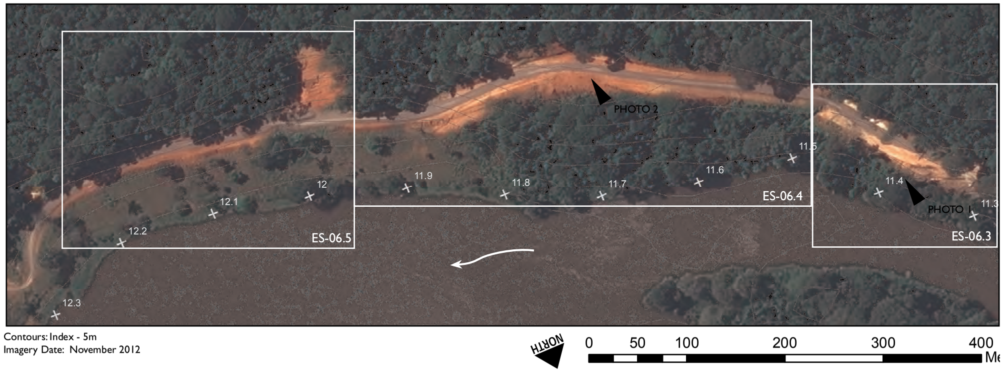


Extent Map

Photo 1. Road cut through steep terrain adjacent to the river (view from river-boat, May 2013)

Panoramic view from helicopter, October 2012.

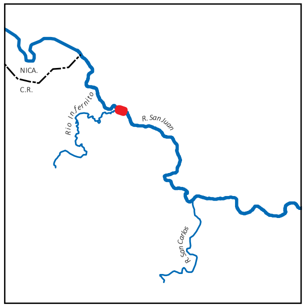
Photo 2. Road cut through steep terrain adjacent to the river (View from helicopter, May 2014)



Contours: Index - 5m
Imagery Date: November 2012

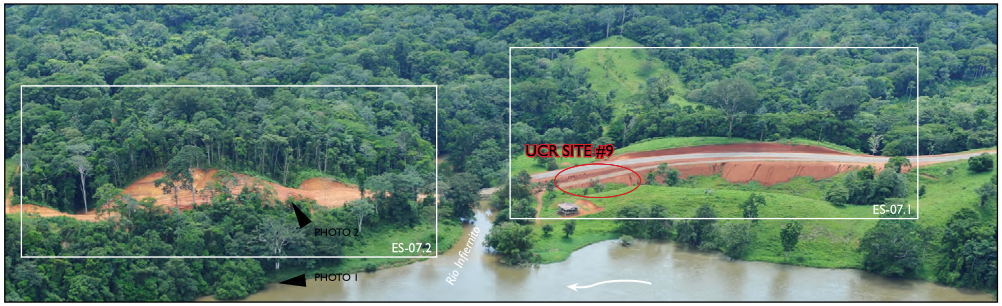
Severe Eroding Area 07a

RKM 13.7 to 14.4



Extent Map

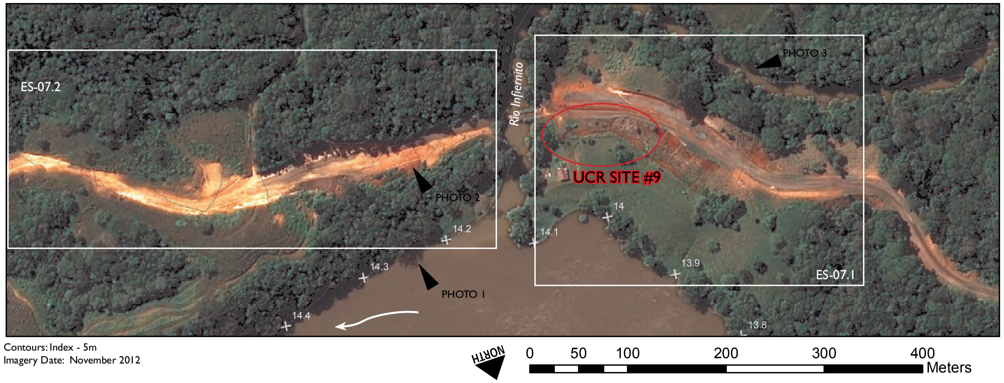
Photo 2. Road cut through steep terrain adjacent to the river (from Mende & Astorga 2013, p37)



Panoramic view from helicopter, October 2012.

Photo 1. Fresh sediment deposit at toe of slope below road cut (May 2013, from riverboat).

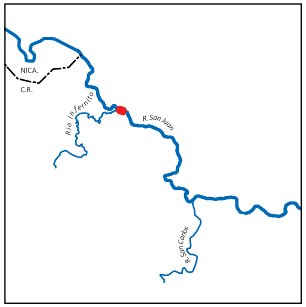
Photo 3. Road cut through steep terrain adjacent to the river (from Mende & Astorga 2013, p37)



Contours: Index - 5m
Imagery Date: November 2012

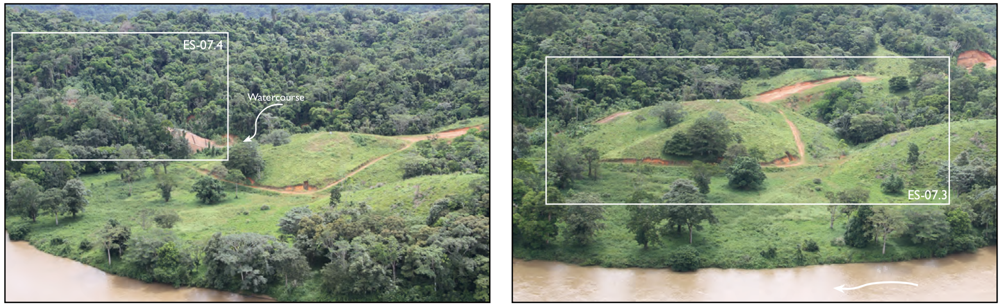
Severe Eroding Area 07b

RKM 14.4 to 15.2



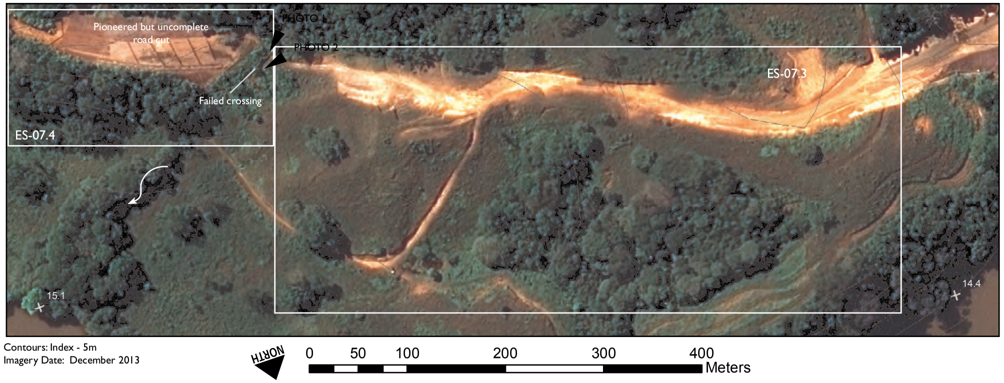
Extent Map

Photo 1. Gully through road and pioneered but incomplete road cut through steep terrain (from Mende & Astorga 2013, p38).



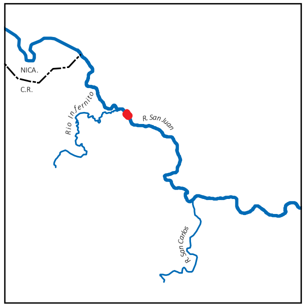
Panoramic view from helicopter, October 2013.

Photo 2. Aerial view of gully through pioneered but incomplete road cut (from Mende & Astorga 2013, p38).



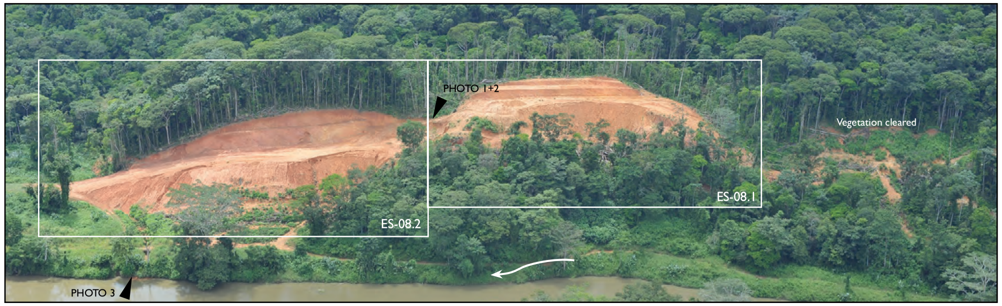
Contours: Index - 5m
Imagery Date: December 2013

Severe Eroding Area 08
RKM 15.6 to 16.5



Extent Map

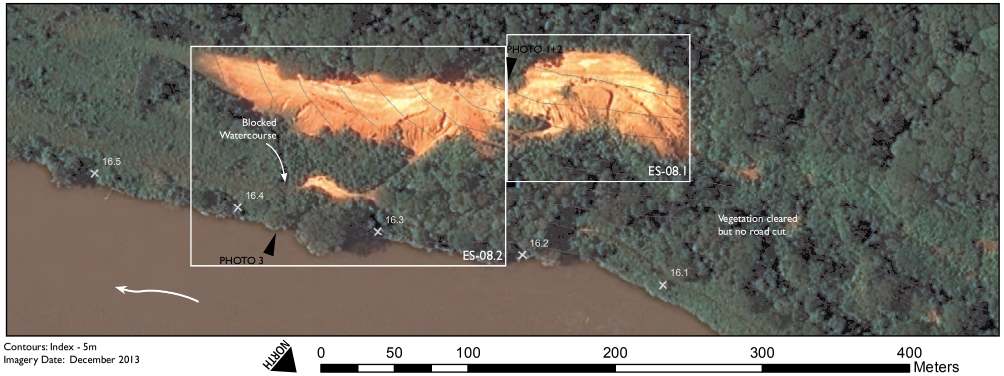
Photo 1. Gully through pioneered but incomplete road cut through steep terrain (from Mende & Astorga 2013, p40).



Panoramic view from helicopter, October 2012.

Photo 2. Pioneered but incomplete road cut through steep terrain (from Mende & Astorga 2013, p40).

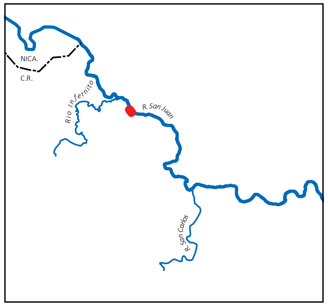
Photo 3. Gully through road and pioneered but incomplete road cut through steep terrain (view from riverboat, May 2013).



Contours: Index - 5m
Imagery Date: December 2013

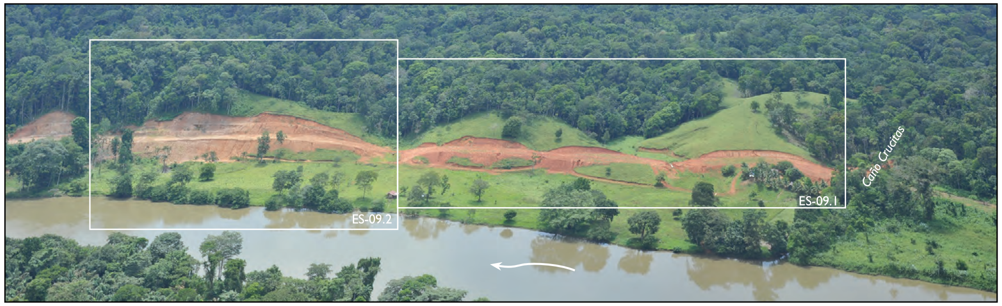
Severe Eroding Area 09a

RKM 17.2 to 17.9



Extent Map

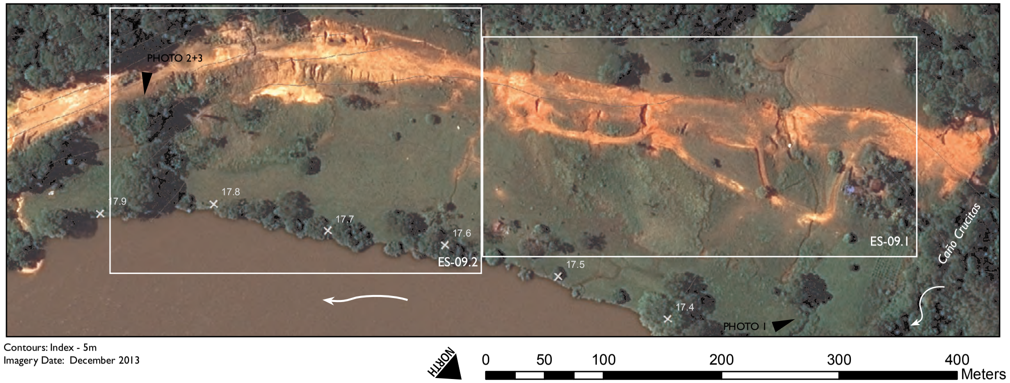
Photo 1. Caño Crucitas confluence with San Juan River just downstream from road crossing (view from riverboat October 2012).



Panoramic view from helicopter, October 2012.

Photo 2. Eroding fill prism with drainage path leading to river (from Mende & Astorga 2013, p43).

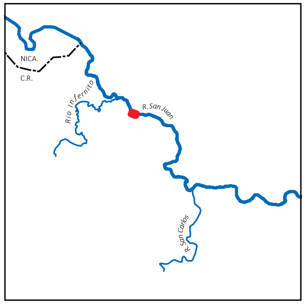
Photo 1. Eroding fill prism placed across drainage path (from Mende & Astorga 2013, p43).



Contours: Index - 5m
Imagery Date: December 2013

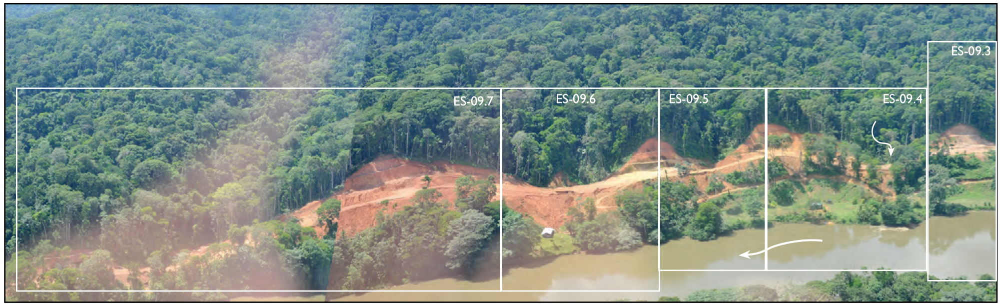
Severe Eroding Area 09b

RKM 17.8 to 18.8



Extent Map

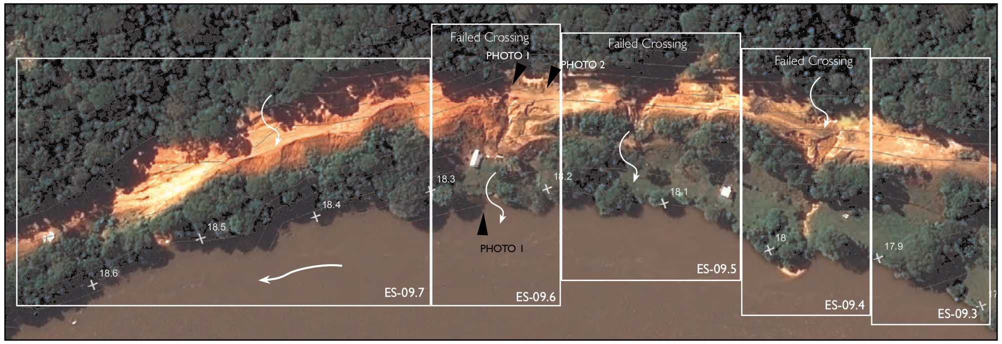
Photo 1. Severely edroding fill prism (view from riverboat, March 2014).



Panoramic view from helicopter, October 2012.

Photo 2. Gullying road fill prism (from Mende & Astorga 2013, p44).

Photo 3. Gullying road fill prism (from Mende & Astorga 2013, p44).

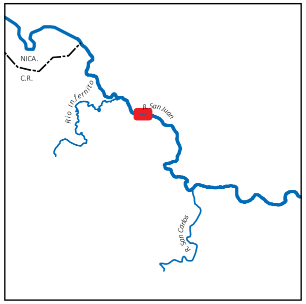


Contours: Index - 5m
Imagery Date: December 2013

NORTH

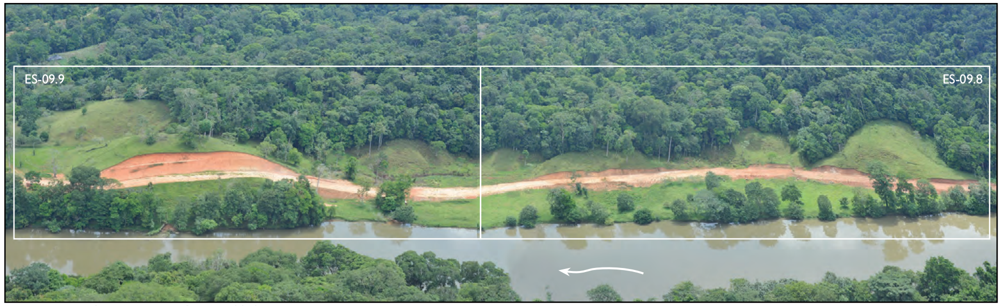
0 50 100 200 300

Severe Eroding Area 09c
RKM 18.8 to 20.6

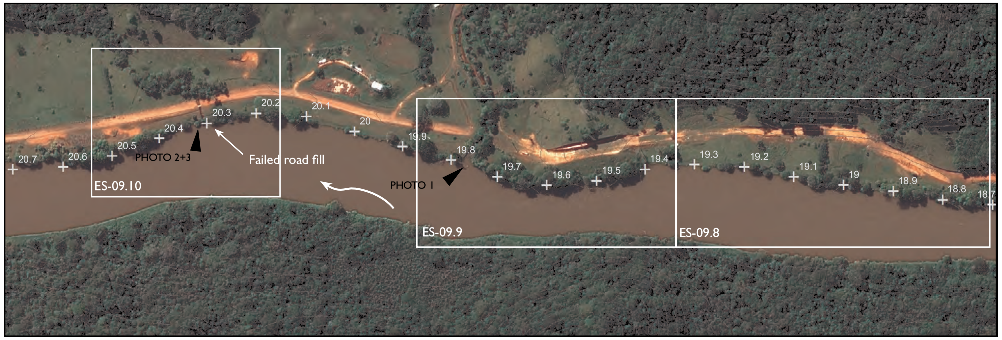


Extent Map

Photo 1. Road fill and crossing at RKM 20.8 (view from riverboat, October 2012).



Panoramic view from helicopter, October 2012.



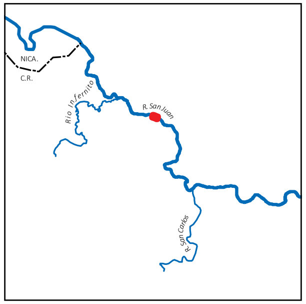
Contours: Index - 5m
Imagery Date: December 2013

Photo 2. Failed road crossing at RKM 21.3 (from Mende & Astorga 2013, p.53). Report notes plans to install a larger diameter culvert.

Photo 3. Failed repaired road crossing at RKM 21.3 (photo taken March 2014). Note destroyed culvert in bottom of photograph.

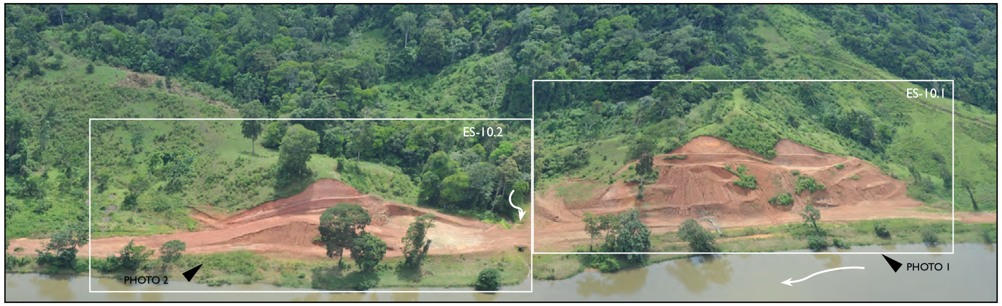
Severe Eroding Area 10

RKM 21.4 to 22.1



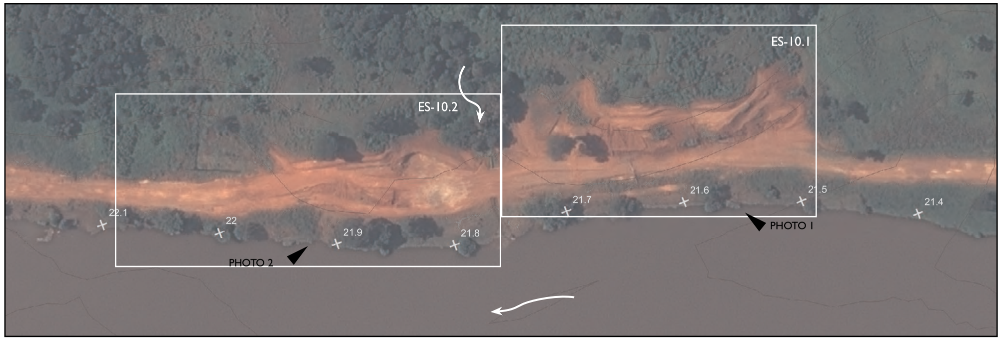
Extent Map

Photo 1. Eroding cutslope within close proximity to the river (view from riverboat, October 2013).



Panoramic view from helicopter, October 2012.

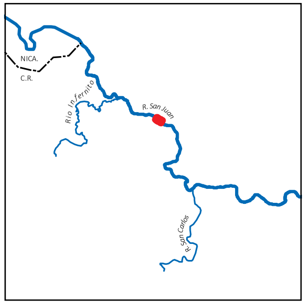
Photo 2. Eroding cutslope within close proximity to the river (view from riverboat, October 2012).



Contours: Index - 5m
Imagery Date: October 2012

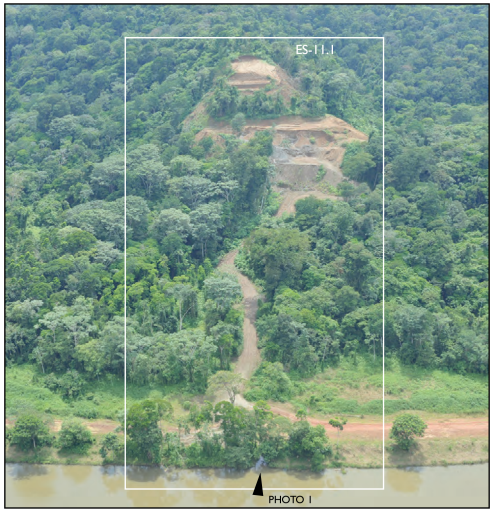
Severe Eroding Area 11

RKM 22.4 to 22.6

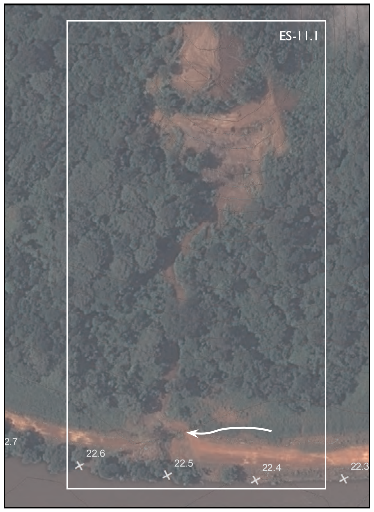


Extent Map

Photo 1. Drainage outlet below quarry site (view from riverboat, October 2012).

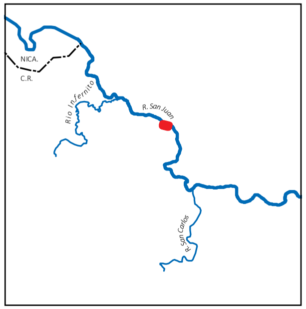


Panoramic view from helicopter, October 2012.



Contours: Index - 5m
Imagery Date: October 2012

Severe Eroding Area 12
RKM 23.6 to 24.4



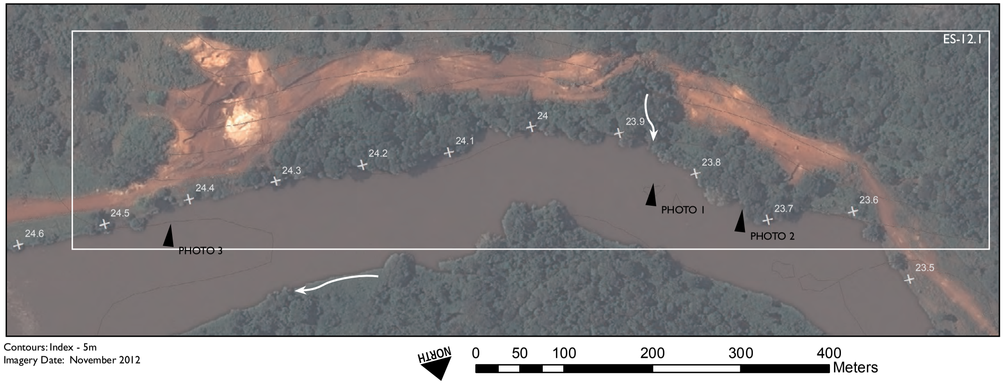
Extent Map

Photo 1. Active road crossing across drainage outlet and below waterfall (La Chorrera) (photo taken March 2014).

Panoramic view from helicopter, October 2012.

Photo 2. Steep eroding road cuts (view from riverboat October 2013).

Photo 3. Steep eroding road cuts (view from riverboat October 2013).

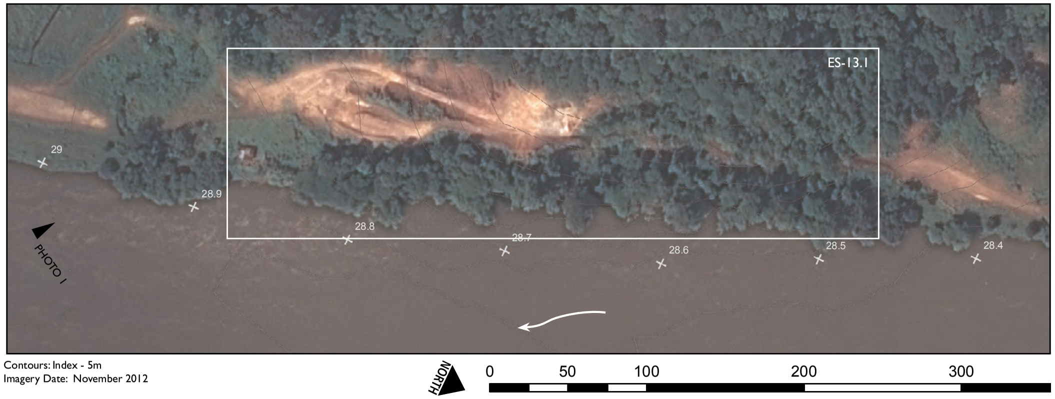


Contours: Index - 5m
Imagery Date: November 2012

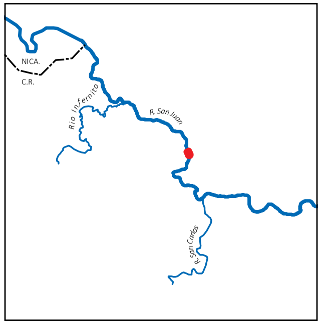
Severe Eroding Area 13

RKM 28.5 to 28.9

Pioneered incomplete road cut, view of from helicopter, October 2012.



Contours: Index - 5m
Imagery Date: November 2012

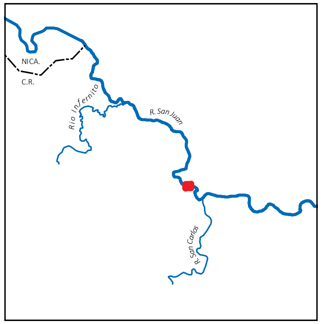


Extent Map

Photo 1. Roadcut pioneered through steep terrain but not completed (view from riverboat, October 2012).

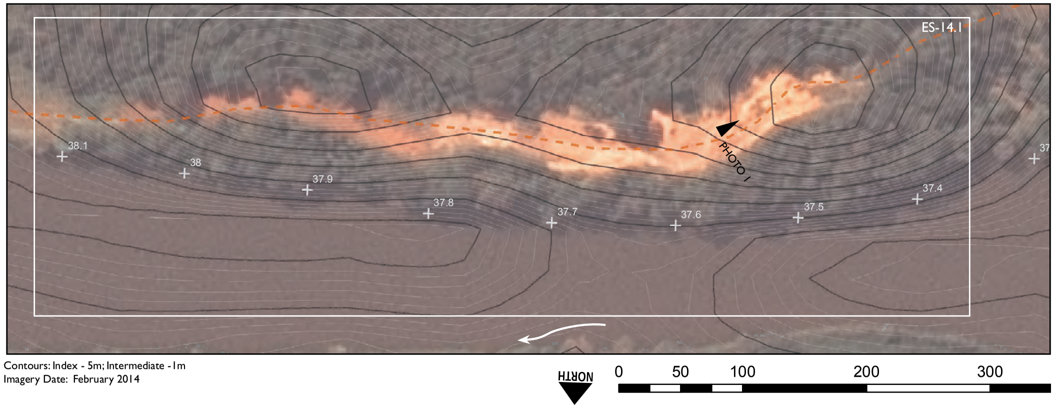
Severe Eroding Area 14

RKM 35.7 to 37.1



Extent Map

Pioneered incomplete road cut, view of from helicopter, October 2012.

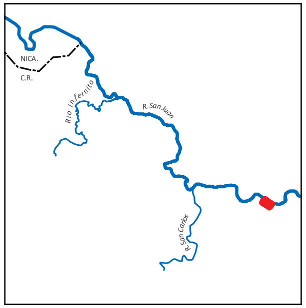


Contours: Index - 5m; Intermediate - 1m
Imagery Date: February 2014

Photo 1. Gullies on roadcut pioneered through steep terrain but not completed (view from helicopter, May 2014).

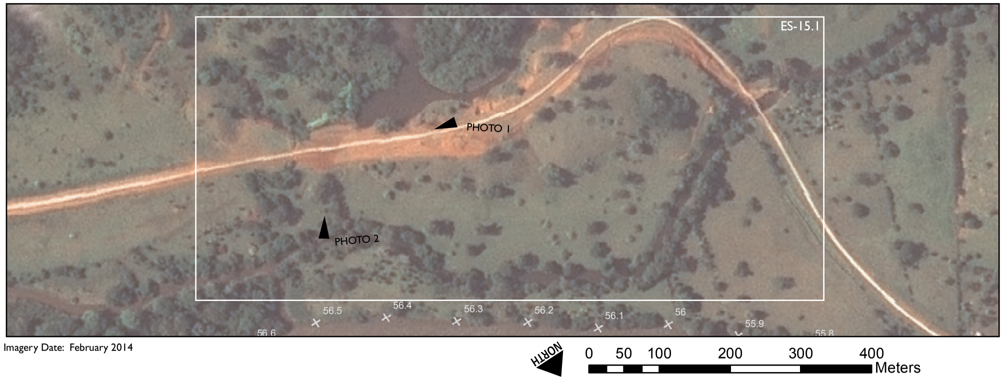
Severe Eroding Area 15

RKM 55.8 to 56.6



Extent Map

View of from helicopter, October 2012.



Imagery Date: February 2014

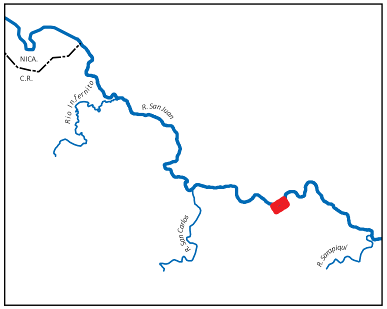
Photo 1. Uncompacted sidecast fillslope along waterbody (from LannameUCR, May 2012).

Photo 2. Fill crossing blocking water body. Evidence of failure. (view from helicopter, October 2012).

Severe Eroding Area 16

RKM 57.3 to 59.2

View of eroding road section from helicopter, October 2012.



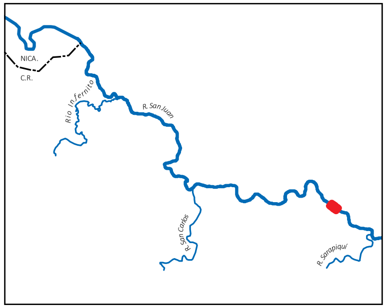
Extent Map

Photo 1. Gullying fill slopes (view from helicopter, October 2012).

Photo 2. Large, steep and exposed cut and fill slopes. See houses for scale (view from helicopter, October 2012).

Severe Eroding Area 17

RKM 72.3 to 73.6



Extent Map

View of eroding road section adjacent to river from helicopter, October 2012.

View of eroding road section adjacent to river from helicopter, October 2012.

Imagery Date: February 2014

Appendix B

Letter from Jeff Campbell of Spatial Solutions, Inc.
28 May 2014

Spatial Solutions, Inc

May 28, 2014

Carlos Argüello-Gómez
The Embassy of Nicaragua
Statenlaan 52
2582 GP, The Hague, Netherlands
<carlosarguello46@gmail.com>

Dear Ambassador Argüello,

I am responding to the statement by Professor Colin Thorne, in which he stated that I "attested" to him that an image I supplied him was exactly the same as an image I supplied to Professor Kondolf. It is the firm policy of Spatial Solutions, Inc. to never divulge information pertaining to any imagery search or imagery acquisition without the client's authorization. I did advise Dr. Thorne that if he supplied me with the specific area-of-interest as well as the parameters of his desired imagery search request, I would provide him with details of what imagery data currently resides in the archives for this area. Dr. Thorne did provide me with such an area-of-interest and I did provide imagery archive results for the area(s) requested.

The imagery delivered to Professor Kondolf was provided in its native format with no manipulation of the original imagery digital numbers (DN's) from that provided directly by the satellite imagery company. If one imports this imagery natively without changing band combinations a color-infrared composite results. Thus I doubt there has been any intentional manipulation of the colors of the displayed imagery.

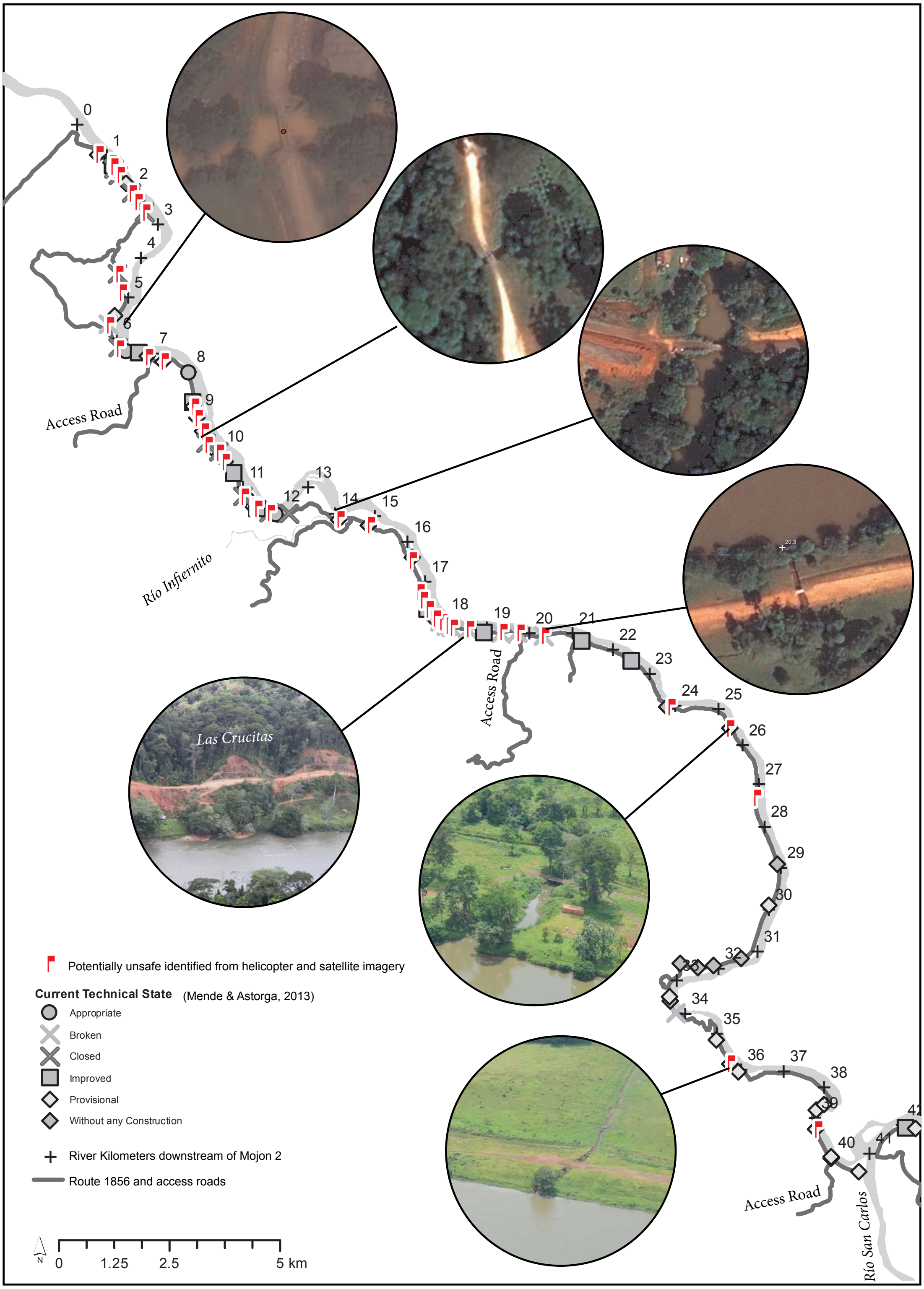
Sincerely yours,

Jeff Campbell
Spatial Solutions, Inc.

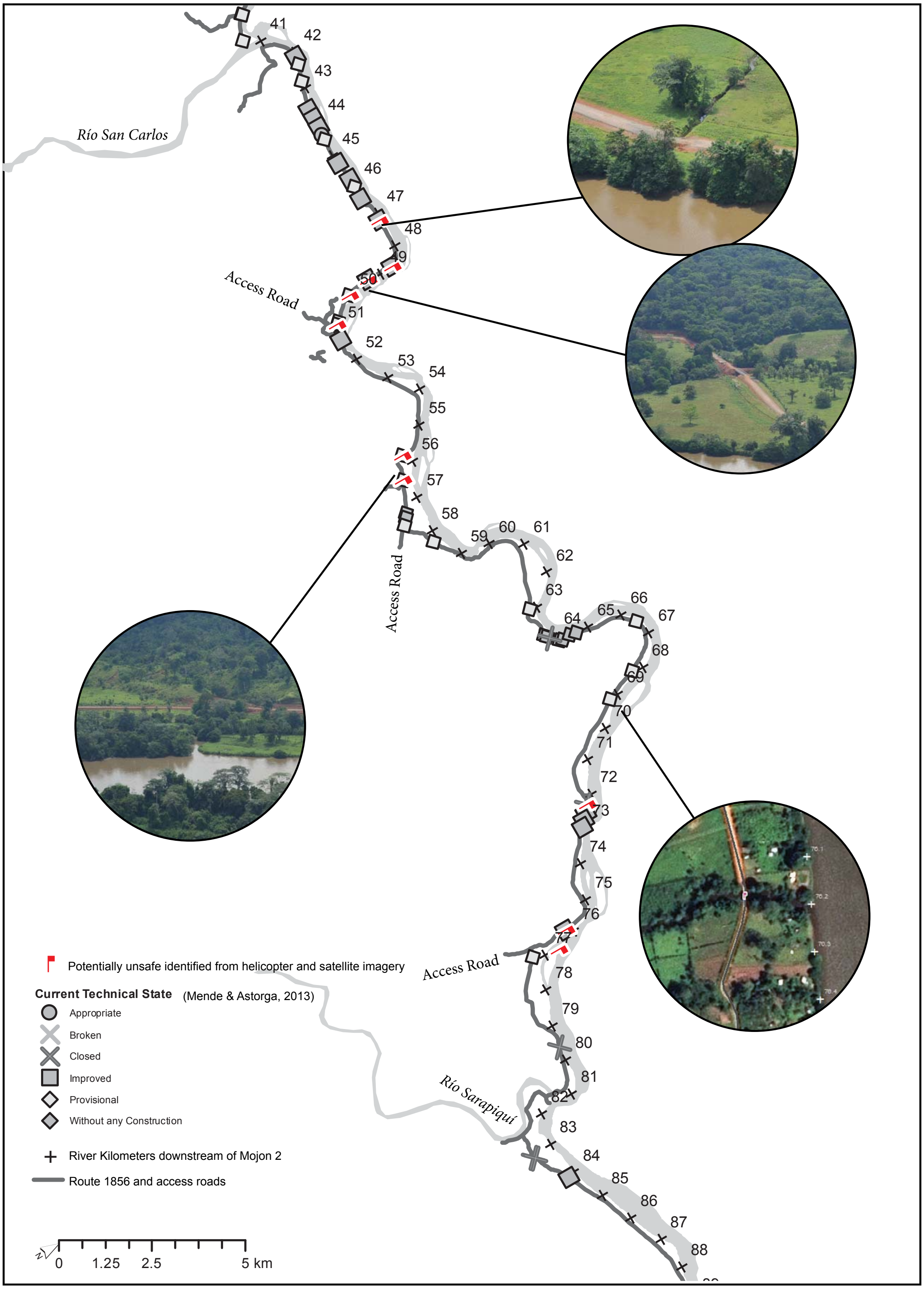
60575 Billadeau Rd. • Bend, Oregon 97702 • Phone: 541-388-8868 • Fax: 541-388-8871 • e-mail: jcampbell@spatial-solutions.com

Appendix C

Map of Potentially Unsafe Stream Crossings



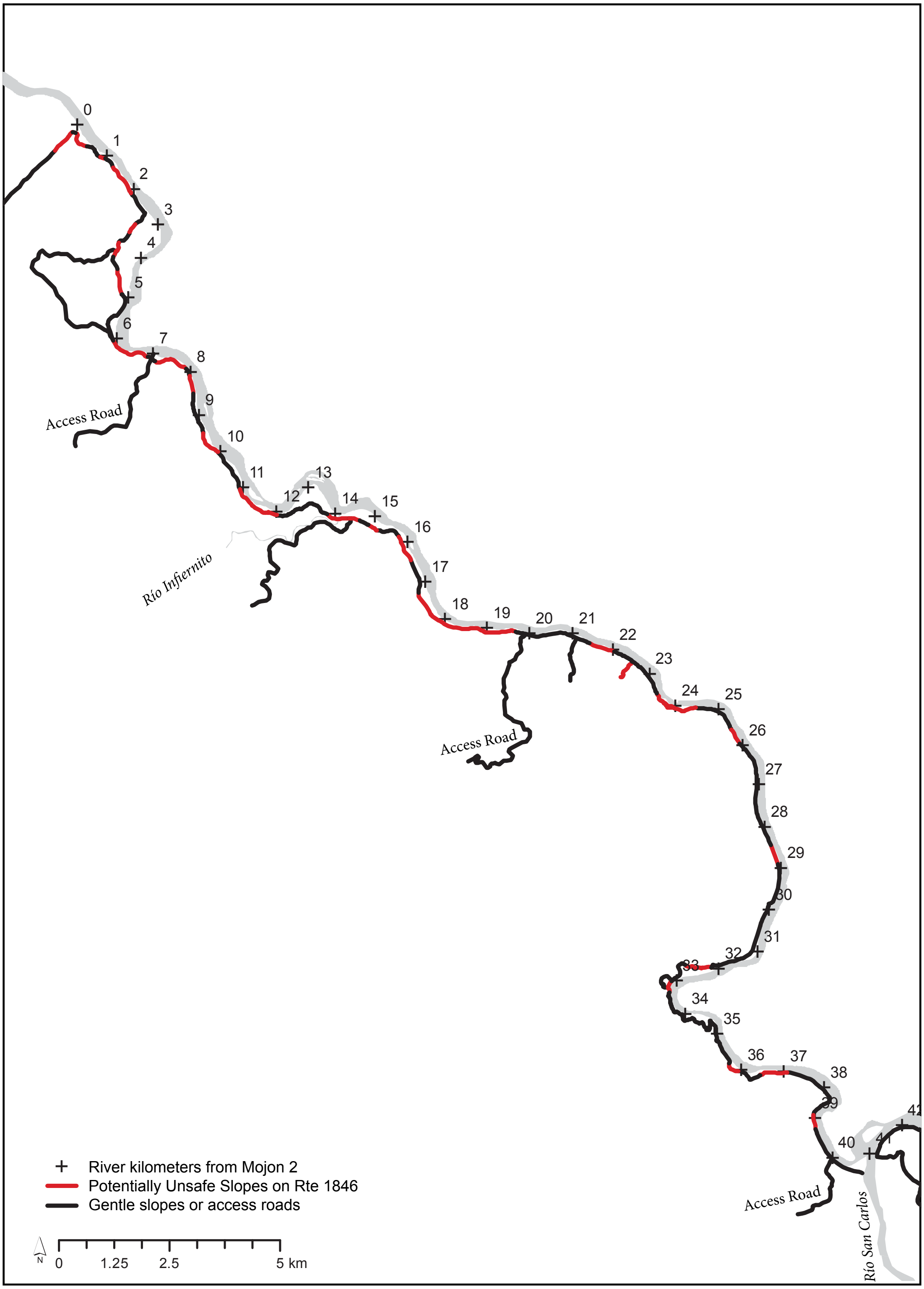
Potentially unsafe road crossings that should require engineers assessment and / or be repaired before being declared safe for passage. Mapped from December 2013 and February 2014 satellite imagery and helicopter flights in 2012, 2013, and 2014.



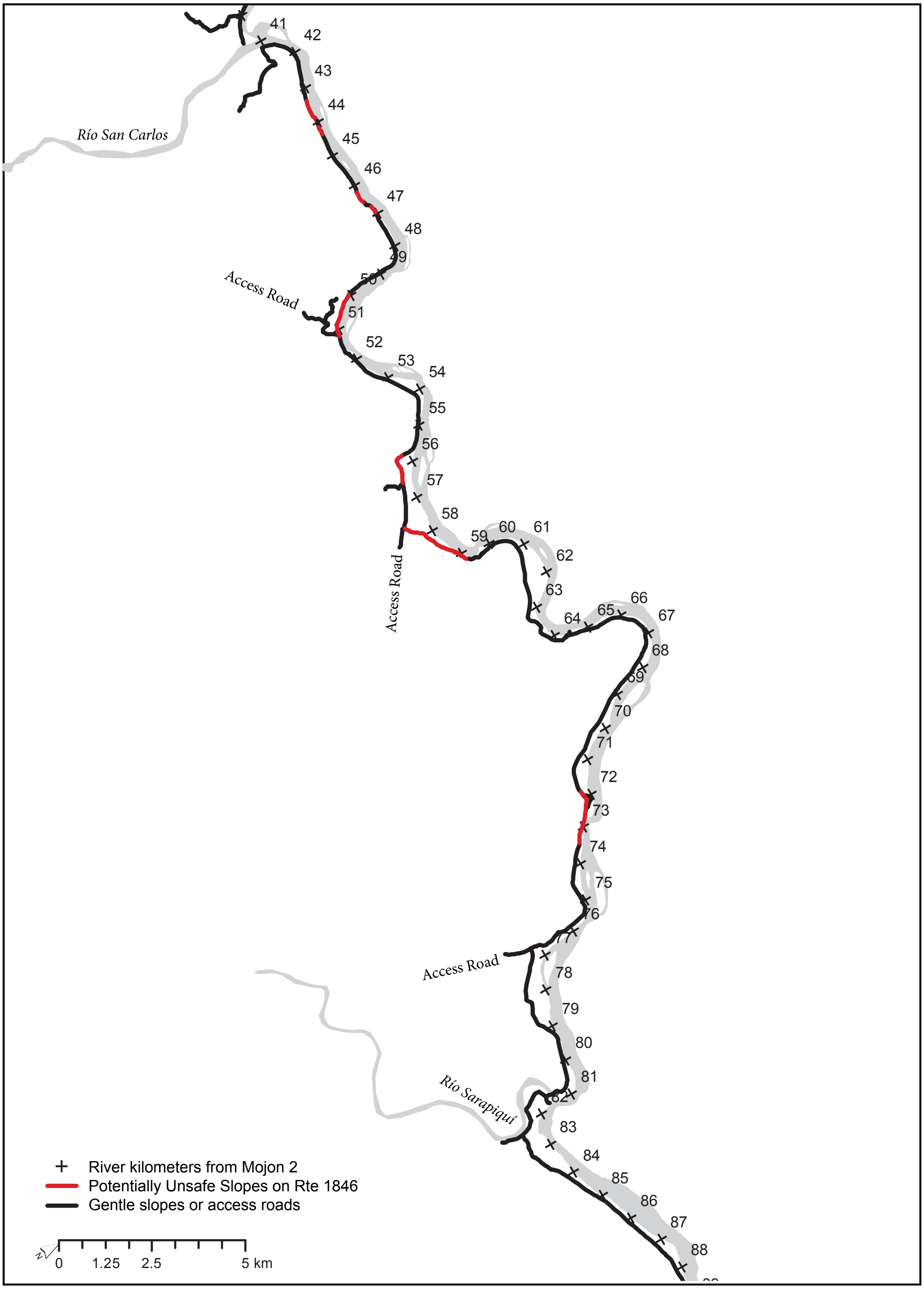
Potentially unsafe road crossings that should require engineers assessment and / or be repaired before being declared safe for passage. Mapped from December 2013 and February 2014 satellite imagery and helicopter flights in 2012, 2013, and 2014.

Appendix D

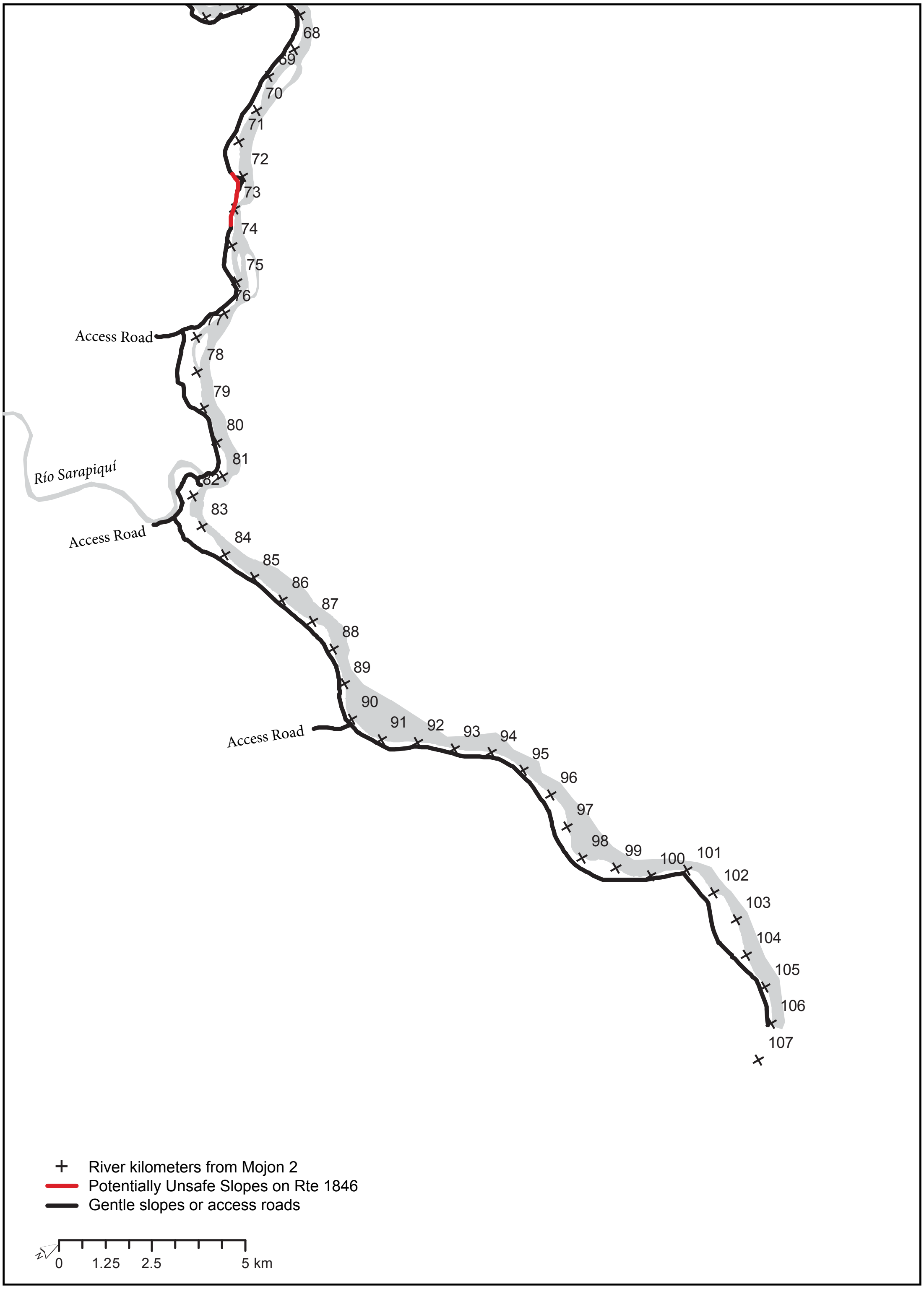
Map of Potentially Unsafe Slopes



Map of potentially unsafe slopes on Rte 1846 identified from helicopter and satellite imagery.



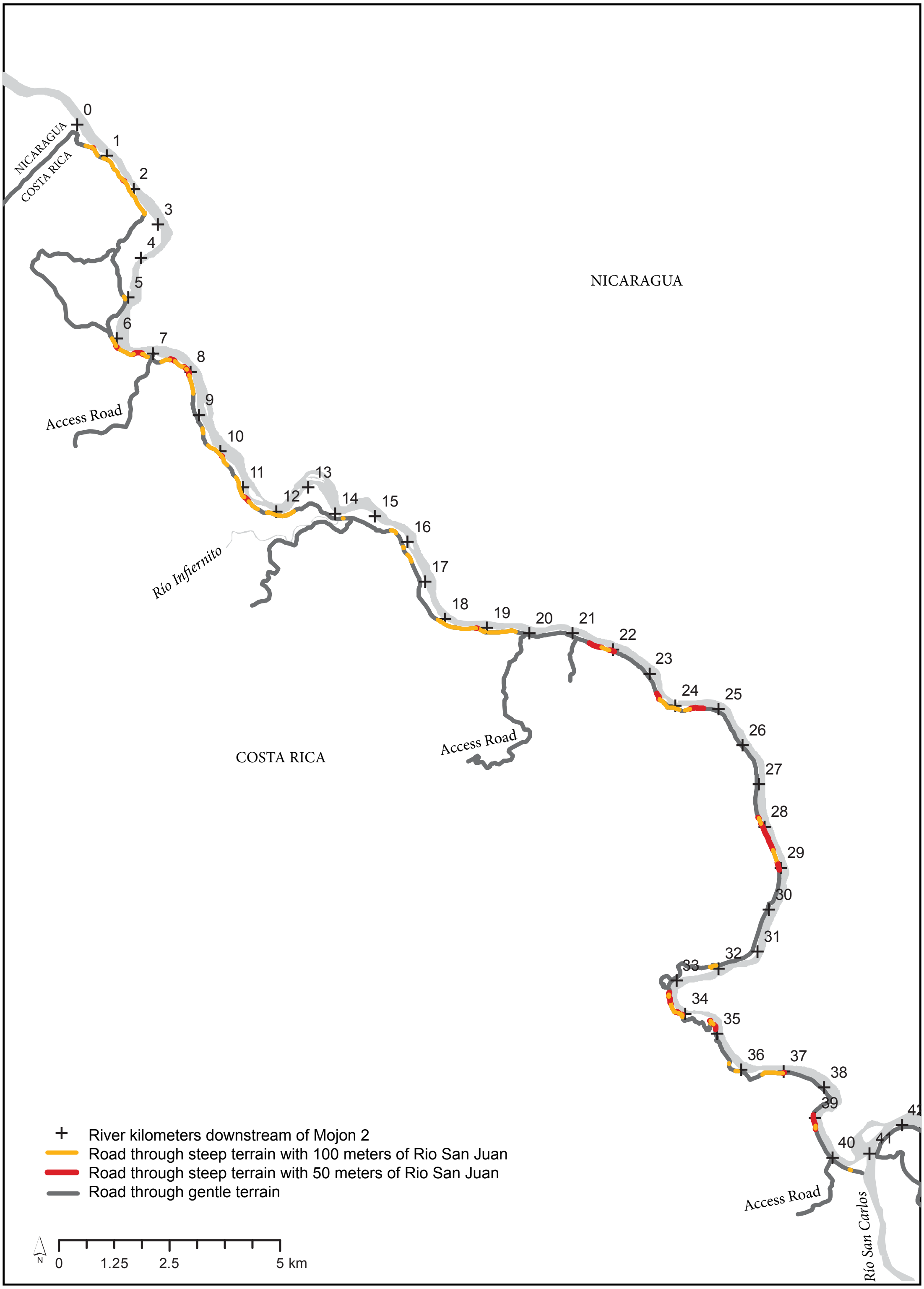
Map of potentially unsafe slopes on Rte 1846 identified from helicopter and satellite imagery.



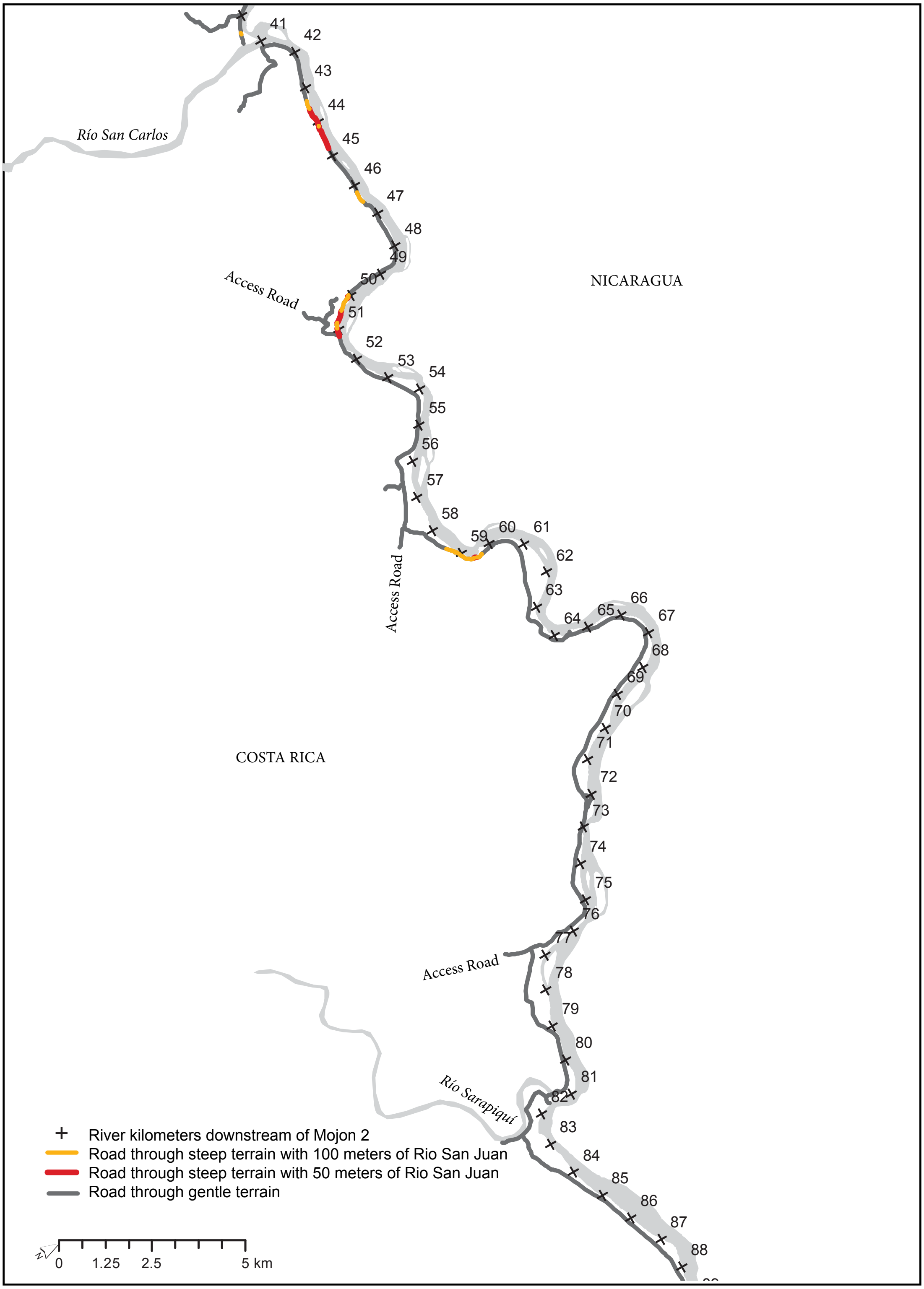
Map of road crossings derived from Mende & Astorga 2013, Annex 6 inventory of water crossings GIS database requested by Nicaragua in 2014. The map of technical states was not provided in Annex 6.

Appendix E

Map of Sections of Route 1856 where Relocation Should be Considered



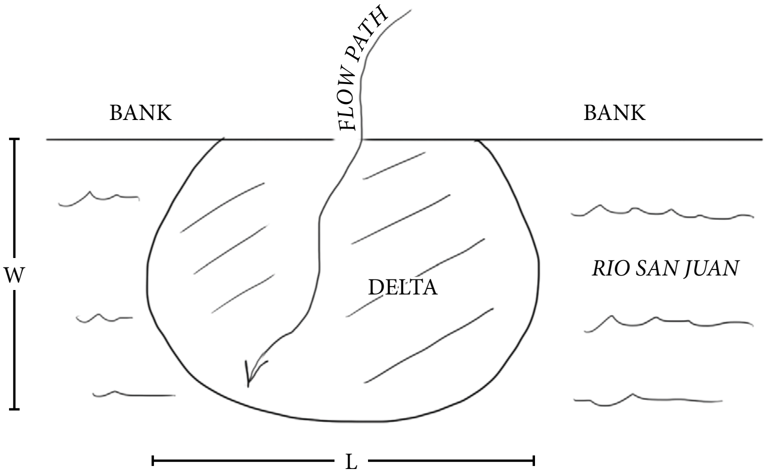
Map highlighting road through steep terrain and within close proximity to Río San Juan where relocation possibilities should be considered.



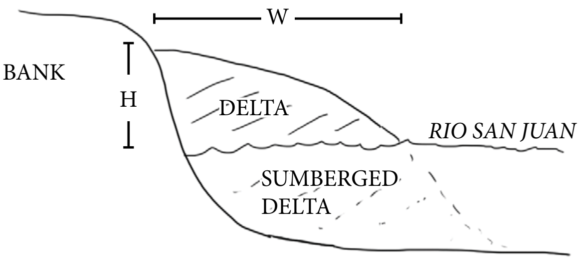
Map highlighting road through steep terrain and within close proximity to Río San Juan where relocation possibilities should be considered.

Appendix F

Road-Derived Deltas in the Río San Juan



PLAN VIEW



PROFILE VIEW

Diagrams of field-measured delta dimensions

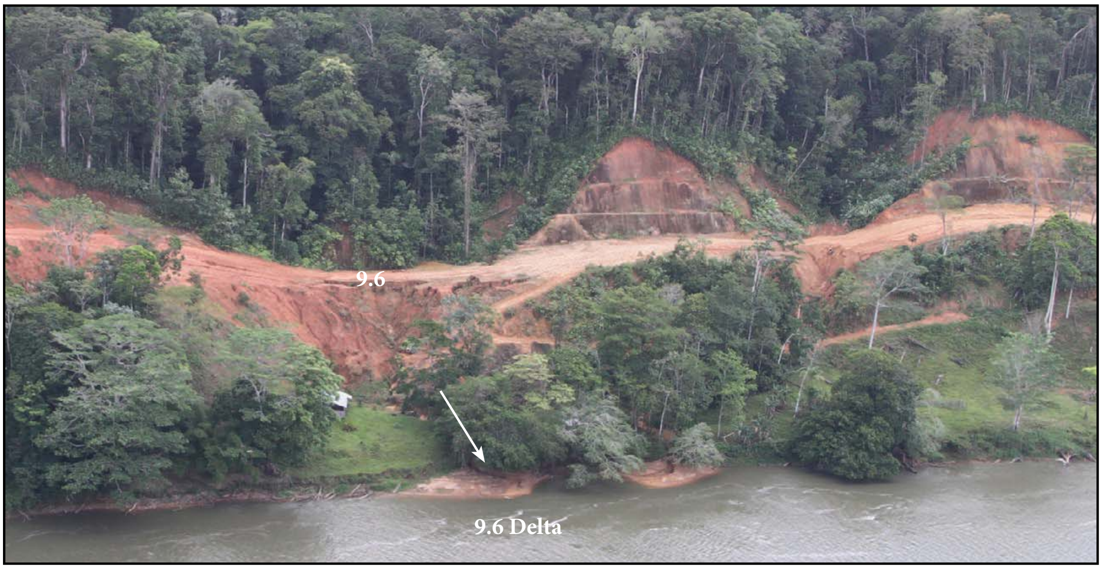


Photo date: May 2, 2014

Delta deposit below Erosion Site 9.6. Ecological Sampling Site 3a.

Width (perpindicular to RSJ) = 15m Length (parallel to RSJ) = 21m Height (above RSJ water surface) = 2m

Photo and measurement date: March 30, 2014

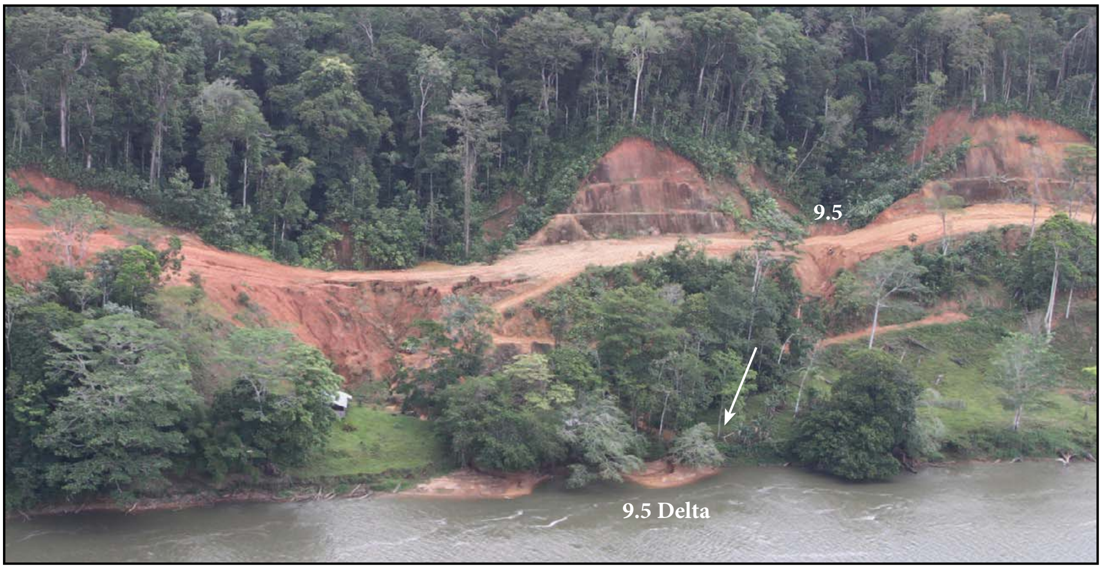


Photo date: May 2, 2014

Delta deposit below Erosion Site 9.5.

Dimensions not directly measured, but similar in scale to 9.6.

Photo date: March 30, 2014

Delta deposit below Erosion Site 9.4. Ecological Sampling Site 2a.

Width (perpindicular to RSJ) = 10m Length (parallel to RSJ) = 25m Height (above RSJ water surface) = 1.8m

Photo and measurement date: March 30, 2014

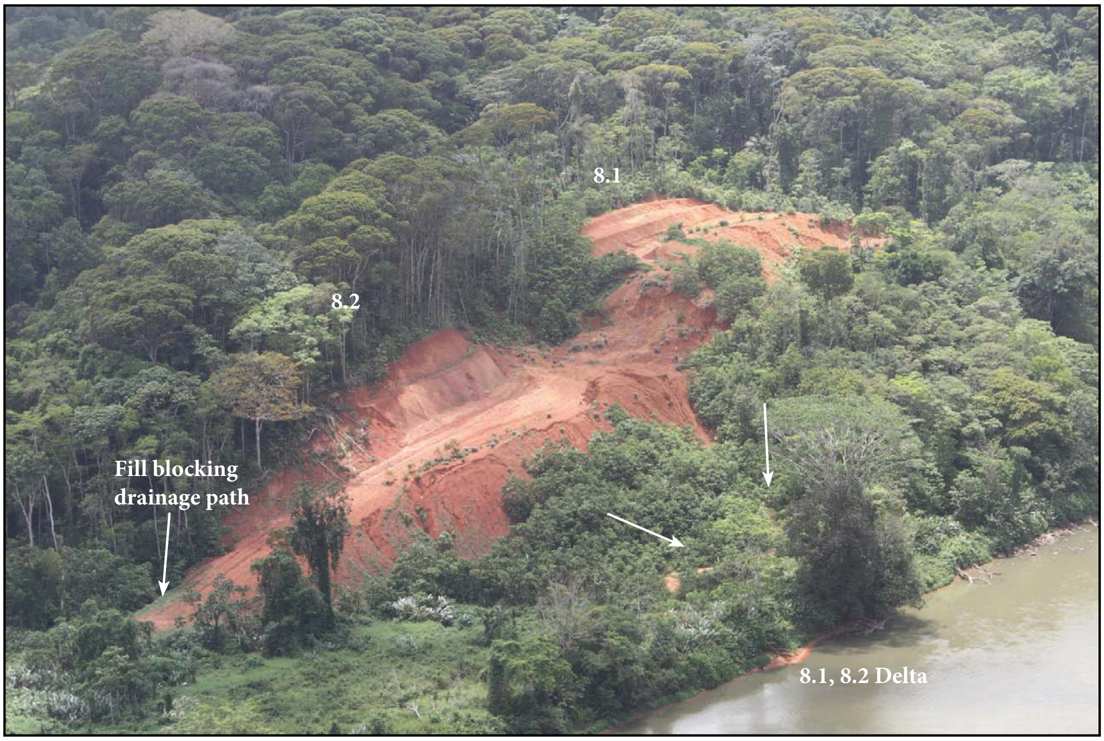


Photo date: May 2, 2014

Delta deposit below Erosion Sites 8.1 and 8.2.

Dimensions not measured in the field.

Photo and measurement date: March 30, 2014

Photo date: May 2, 2014

Delta deposit below Erosion Site 9.7. Ecological Sampling Site 6a.

Width (perpindicular to RSJ) = 21m Length (parallel to RSJ) = 25m Height (above RSJ water surface) = 1.7m

Photo and measurement date: March 30, 2014

Photo date: May 2, 2014

Delta deposit below Erosion Site 9.7. Ecological Sampling Site 7a.

Width (perpindicular to RSJ) = 13m Length (parallel to RSJ) = 30m Height (above RSJ water surface) = 1.6m

Photo and measurement date: March 30, 2014

Photo date: October 17, 2012

Delta deposit at fill crossing failure 20.3 km downstream of Mojon 2. Ecological Sampling Site 8a.

Width (perpindicular to RSJ) = 13m Length (parallel to RSJ) = 15m Height (above RSJ water surface) = 1.5m

Photo and measurement date: March 31, 2014

Photo date: May 2, 2014

Sediment deposit at mouth of Caño Venado, an example of a more natural deposit with a lower and wider profile indicating less rapid deposition. Ecological Sampling Site 4a.

Width (perpindicular to RSJ) = 50m Length (parallel to RSJ) = 50m Height (above RSJ water surface) = 0.75m

Photo and measurement date: March 30, 2014

Appendix G

Roy C. Sidle et al., Unprecedented Rates of Landslide and Surface Erosion along a Newly Constructed Road in Yunnan, China, 57 Nat. Hazards 313 (2011)

Nat Hazards (2011) 57:313–326
DOI 10.1007/s11069-010-9614-6

ORIGINAL PAPER

Unprecedented rates of landslide and surface erosion along a newly constructed road in Yunnan, China

Roy C. Sidle · Takahisa Furuichi · Yasuyuki Kono

Received: 6 December 2008 / Accepted: 2 September 2010 / Published online: 23 September 2010

Abstract Field measurements conducted 4 years after the construction of a new portion of the Weixi–Shangri-La road in Yunnan, China, reveal that unprecedented rates of mass wasting occurred along the road with much of this sediment directly impacting the headwaters of the Mekong River. Landslide erosion (including dry ravel) exceeded 33,000 t ha^{-1} year^{-1} along the most severely eroded sections of the road and averaged more than 9,600 t ha^{-1} year^{-1} along the surveyed 23.5 km of road; these values are the highest ever reported for road-related landslides. While surface erosion was only about 7% of the total erosion from the road, it is still more than an order of magnitude higher than typical surface erosion rates from disturbed lands in Southeast Asia. Combined landslide and surface erosion from this road delivered an estimated 19 times more sediment to the river than the remaining 99.6% of the contributing catchment. These sediment inputs are aggrading local channels, promoting downstream sediment transport, degrading aquatic habitat, and creating the possibility for a future debris flood or hyperconcentrated flow.

Keywords Road-related landslides · Dry ravel · Channel aggradation · Gulley erosion · Mekong River · Rural development

1 Introduction

Mountain roads are the most prodigious source of landslide sediment associated with all widespread land uses, yet the consequences of road building on the environment are not

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fully appreciated or embraced by many government agencies, conservation groups, and international donors (Sidle and Ochiai 2006). Particularly in developing countries, poorly planned and constructed mountain roads leave a legacy of sedimentation in streams and rivers and frequently cause casualties and property damage (e.g., Bansal and Mathur 1976; Haigh 1984; Jones and Lee 1989; Sidle et al. 2006; Dykes and Welford 2007). Even in Japan, which arguably invests the greatest amount of resources in erosion control along roads, landslide disasters occur associated with these corridors (Sidle and Ochiai 2006).

Roads excavated into steep mountain slopes create instability in the following ways: (1) undercutting steep slopes, thus removing support; (2) overloading and oversteepening fillslopes, including within the road prism; and (3) altering natural hydrologic pathways and concentrating water onto unstable portions of the hillslope (Sidle and Ochiai 2006). Additionally, roads intercept subsurface flow from cutslopes during storms and concentrate overland flow on their compacted or paved surfaces. This water is then discharged downslope at concentrated drainage points where it may cause extensive surface erosion and even channel headcutting (Sidle et al. 2004; Ziegler et al. 2006). When road surfaces are unpaved, much surface erosion may occur due to storm runoff (e.g., Baharuddin et al. 1995; Ziegler et al. 2004). Surface erosion also occurs on exposed cut- and fillslopes (e.g., Megahan and Ketcheson 1996; Sidle et al. 2004). Road design, construction practices, and particularly location can ameliorate these impacts; however, any road cut into a steep hillslope will exert some destabilizing affect. Engineering structural controls on road stability (e.g., Holtz and Schuster 1996) have variable levels of success, but are prohibitively expensive in remote regions of developing countries (Sidle and Ochiai 2006).

Significant landslide and erosion problems associated with mountain roads are evident in developing countries of Asia where road systems are rapidly expanding due to presumed needs for economic and social development, national defense, evacuation routes, and increasing tourism (Haigh 1984; Sakakibara et al. 2004; Castella et al. 2005; Sidle and Ochiai 2006). In particular, the total mileage of rural roads in China increased by 5.5-fold during the 30-year period from 1978 through the end of 2007 (China Road Construction Report 2008). Here, we present some of the first comprehensive road erosion and landslide estimates for the rapidly developing region of northern Yunnan Province, China, along the new Weixi–Shangri-La road.

The primary objective of this investigation is to quantify the amount of landslide and surface erosion emanating from different parts of a newly developed mountain road in Yunnan, China, as well as for different erosion susceptibility categories. Also, the contributions of sediment from the road are compared to potential sediment sources from other parts of the terrain. Finally, we assess the connectivity of road-related sediment sources to the upper tributaries of the Mekong River as well as infer possible downstream and other environmental consequences.

2 Study area

Northwestern Yunnan has been a poor, remote mountainous region of China (Fig. 1), but is now experiencing rapid growth due to tourism and rural economic development (e.g., Krongkaew 2004; Nyaupane et al. 2006). This region includes the Three Parallel Rivers of Yunnan Protected Areas, which was designated as a UNESCO World Heritage Site in 2003. The north–south trending Hengduan Mountains create the steep gorges of the Salween, Mekong, and Jinsha Rivers, which, at their nearest proximity, are 18 and 66 km apart. The former two rivers flow through other Southeast Asian nations, and the latter is

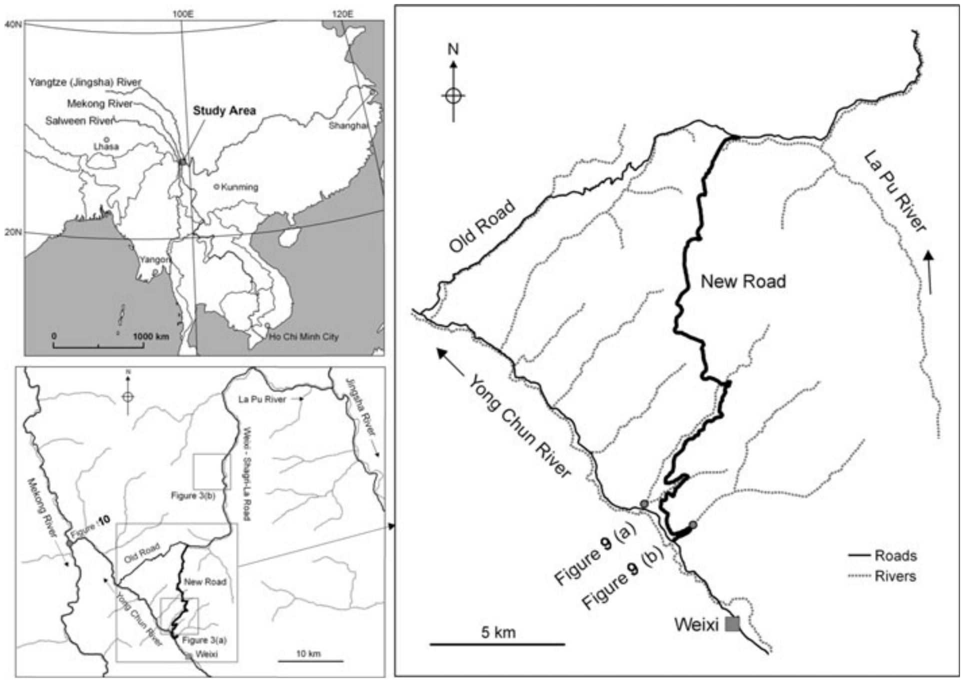

Fig. 1 Map of the study area showing the location of the recently constructed Weixi–Shangri-La road

the upstream reach of the Yangtze River (Fig. 1). A new 28-km segment of the Weixi–Shangri-La road was constructed in 2002 through steep mountains near and along headwaters of the Yong Chun River (tributary to the Mekong River) to expedite travel to Weixi; the old road, which originated near the divide between the Jinsha and Mekong River basins and traversed through higher elevations descending to the town of Weixi, was 44 km long and was impassable during limited periods in winter (Fig. 1). Elevation in the study area (latitude: 27°11′N–27°20′N; longitude: 99°16′E–99°20′E) ranged from approximately 3,000 to 3,750 m. The new road was blasted into weathered bedrock along the steep mountainsides exposing cutslopes up to 80 m high and depositing the waste rock and soil onto the oversteepened fillslopes. Due to the uniformly steep gradients below the road, much of the sediment generated during construction and, most notably afterward via landslides and surface erosion, was deposited directly into the tributaries of the Yong Chun River or its riparian area (Fig. 2).

This area experiences a temperate climate with monsoon storms occurring from April to October with a short period of dry weather in June. Average annual rainfall is 968 mm; higher elevations generally experience larger amounts of precipitation (Weixi County 1999). Hillsides along the most unstable sections of the road are very steep (31° to >43°), with especially steep and uniform slopes extending to the tributaries of the Yong Chun River. Slopes along slightly more stable portions of the road ranged from 25 to 37° but were locally steeper. The region is tectonically active, although large earthquakes did not occur near this area in the interval between road construction and our field surveys. Bedrock is highly sheared, folded, and fractured and is largely composed of ignimbrite and rhyolite with some metamorphic inclusions. Some landslides can be seen on relatively undisturbed hillslopes in this area; thus, the road corridor was naturally unstable;

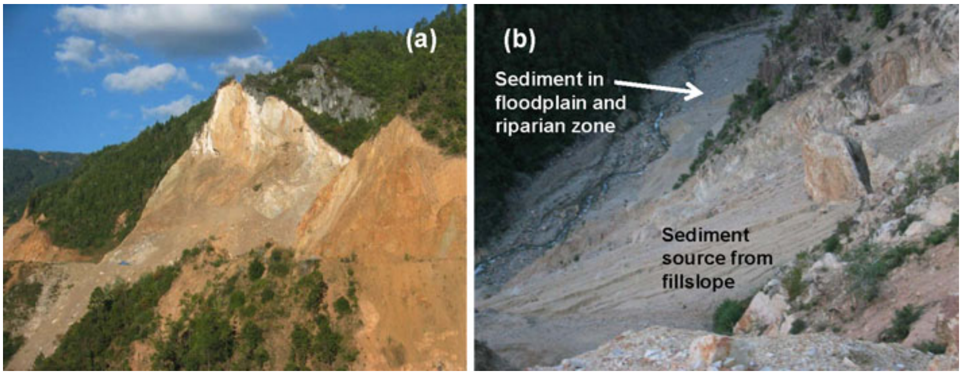

Fig. 2 **a** The large cutslope failure that killed six people traveling along the road in a minivan in summer 2006; and **b** sediment from displaced cutslope sediment and failures in the fillslope that directly entered the stream channel

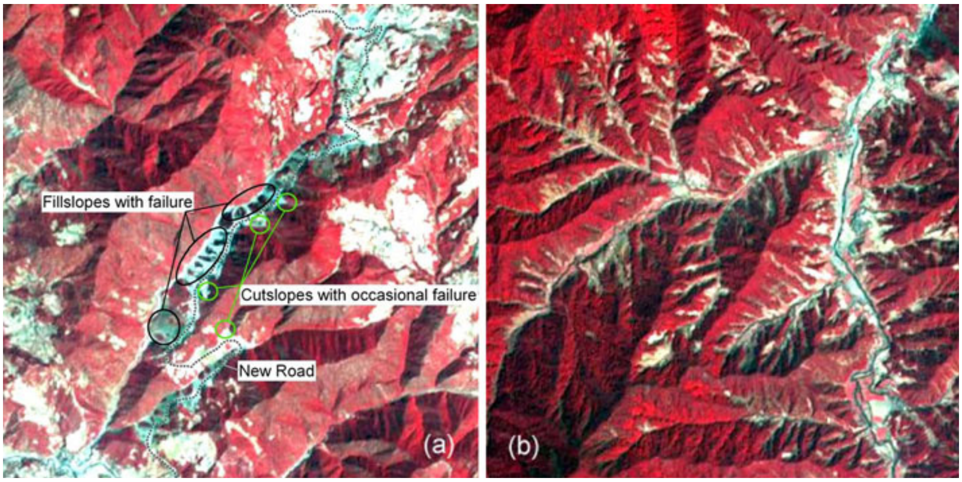

Fig. 3 Aerial view of landslides in this region by ASTER false images. Locations of both frames are shown in Fig. 1. The left frame (**a**) shows cutslope and extensive fillslope failures related to the Weixi–Shangri-La road, while the right frame (**b**) shows a lesser extent of landslides on steep slopes in a nearby catchment unaffected by road construction

nevertheless, a cursory examination shows that the recently constructed Weixi–Shangri-La road markedly increased landslide erosion (Fig. 3). During construction, it appears that little or no action was taken to control blasting, and virtually, no attention was paid to road location and erosion control. The location of the road simply corresponds to the most direct transport route through this mountainous terrain. Additionally, no engineering structures were installed to mitigate unstable sections of the road (e.g., high cuts into fractured and weathered bedrock; large fill placements on steep slopes).

In addition to the sediment generated from this road and its effect on river systems, road-related landslides present a hazard to traffic. During summer of 2006, six people traveling down this portion of the Weixi–Shangri-La road in a minivan were killed by a landslide originating from a steep cutslope that was blasted into the mountainside (Fig. 2a).

Such a disaster on a lightly traveled road is indicative of the high frequency of landsliding that was observed in the field.

3 Methods

In October 2006, landslides and surface erosion were visually assessed along a 23.5-km portion of the new Weixi–Shangri-La road; the remaining 4.5 km of the new road was in the valley bottom near Weixi or outside the Mekong Basin near the divide. The combined landslide/surface erosion along the entire 23.5 km of road was significant and was qualitatively categorized as moderately severe, severe, or very severe. The general criteria for the three landslide/erosion categories were based on conditions noted for each kilometer of road: (1) moderately severe—one to three moderate-sized landslides (>300 m^3) and minor surface erosion or no moderate-sized large landslides and significant surface erosion; (2) severe—greater than three, but less than six moderate-sized landslides or one to three moderate-sized landslides and severe surface erosion (i.e., major gullies); and (3) very severe—six or more moderate-sized landslides and significant surface erosion. For each category, a representative 0.75- to 0.90-km section of road was then surveyed in detail for both landslide and surface erosion.

Surface erosion was estimated on disturbed cut- and fillslopes based on the measurements of several hundred soil erosion pedestals at the site. Such estimates appear to give conservative yet reliable estimates of cumulative surface erosion in sites where such well-formed soil pedestals develop (Sidle et al. 2004). Where slopes had only small gullies (<0.5 m deep), this erosion was conservatively estimated based on pedestal data. Slope dimensions were measured by a distance meter (range finder), and the area of active surface erosion was multiplied by the average height of the soil pedestals and then divided by the time since road construction (4 year) to calculate an average surface erosion rate. Deeper gullies were mapped and volumes estimated from dimensional analysis based on gulley shape, length, and measured or estimated depth (Fig. 4). Given the rather crude metrics used to estimate surface erosion, errors associated with values derived would likely be in the order of ±10–15% with a bias toward underestimation.

Lengths and widths of landslides were measured with metric tapes where possible or with a distance meter (range finder). Depths around the flanks of landslides on cut- and fillslopes were measured directly where possible and otherwise estimated to facilitate calculation of landslide volumes by dimensional analysis. Based on the simple field methods and approximations used to calculate landslide volumes, errors are likely in the range of ±10%. Nevertheless, such measurements are undoubtedly more accurate than values derived from remote sensing or GPS (e.g., Barbarella et al. 2000; Tsutsui et al. 2007). Volumes of landslides and surface erosion were converted to mass using measurements of bulk density. For surficial material (surface erosion, including gullies), the measured mean bulk density of surface soil was used (1.34 g cm^{-3}). Mass wasting features (landslides and dry ravel) had higher amounts of rock materials. Based on 30% rock content by volume estimated conservatively in the field, bulk density of landslide and dry ravel materials was 1.73 g cm^{-3}.

Dry ravel, the gravitational downslope movement of individual soil grains, aggregates, and coarse fragments by rolling, sliding, or bounding (Sidle and Ochiai 2006), was a significant process on some steep cutslopes and fillslopes. Because little quantitative data are available on this poorly studied mass wasting process, we used a value of 20 m^3 ha^{-1} $year^{-1}$ on the steepest slopes (>40°), half of this value (10 m^3 ha^{-1} $year^{-1}$)

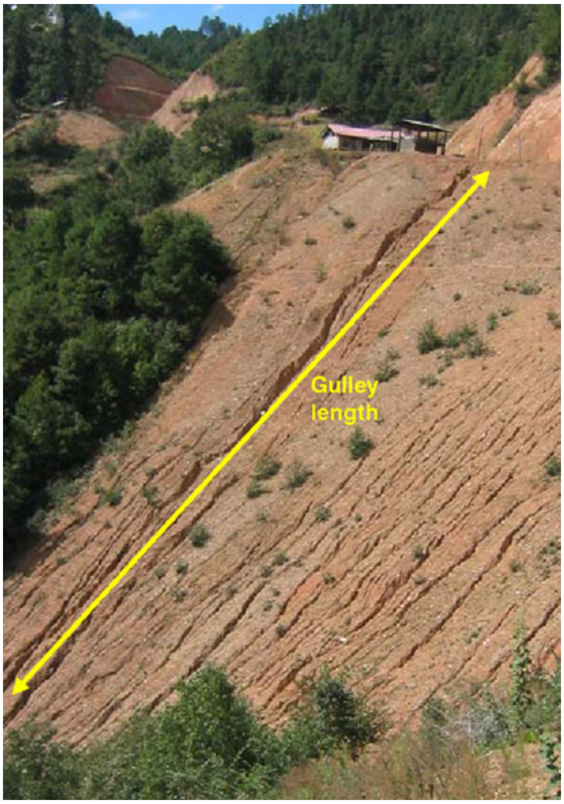

Fig. 4 Extensive gulley erosion occurred on road fillslopes in the severe erosion category. For gullies deeper than 0.5 m, dimensions were measured and eroded volume was calculated

on slope gradients from 30 to 40°, and no ravel was assumed on slopes <30°. These ravel estimates are based on field data from Kumanodaira, Gunma Prefecture, Japan (R.C. Sidle, unpublished data).

Erosion and landslide estimates were calculated separately for cut- and fillslopes. These values are expressed based on the 'footprint' of the road—i.e., sediment mass per unit area of road per year. Road area is calculated based on the product of the length of a given surveyed section and the average width of the road (20 m from the base of the cutslope to the outer edge of the fillslope). Landside and surface erosion data were then extrapolated to the entire 24.5-km road section based on the prior visual estimates of erosion/landslide severity categories.

4 Results and discussion

4.1 Comparison of mass and surface erosion

The ratio of mass wasting (includes landslides plus dry ravel) to surface erosion ranged from about 1.6 in the severe erosion road category to nearly 16 in both the moderately severe and very severe categories (Fig. 5). The high mass wasting to surface erosion ratio in the moderately severe category is due to the lack of gulley erosion; in contrast, the lower mass wasting to surface erosion ratio in the severe erosion category coincides with the highest gulley erosion (145 t ha^{-1} year^{-1}) of all erosion categories (Fig. 4). For the three

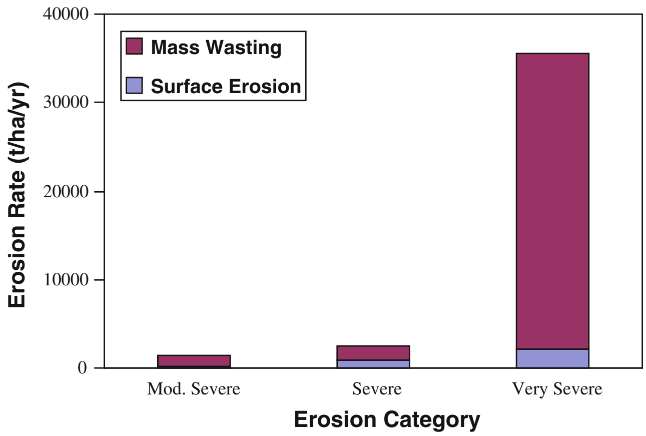

Fig. 5 Comparison of mass erosion with surface erosion in three different categories of erosion severity along the Weixi–Shangri-La road

inventoried road sections (0.75–0.90 km), only one and two moderately large (>2,000 m^3) landslides were associated with the moderately severe and severe erosion sections, respectively; in contrast, six large (>7,500 m^3) landslides were documented in the very severe erosion section. Thus, it is the dominance of larger landslides in this very severe category that sets it apart from the other classes; mass wasting was 33,450 t ha^{-1} year^{-1} in the very severe category compared to 2,120 t ha^{-1} year^{-1} for surface erosion (Fig. 5). Nevertheless, these surface erosion estimates are extremely high values compared to surface erosion on disturbed lands in Southeast Asia (e.g., Sidle et al. 2006).

4.2 Mass wasting

Slightly more landslides were inventoried along cutslopes compared to fillslopes, but the rate of landslide sediment production from fillslopes was about 17 and 100 times higher than rates from fillslopes for the severe and very severe erosion sections, respectively (Fig. 6). In the very severe erosion section of the road (0.85 km in length), six large (>7,500 m^3) landslides were inventoried on fillslopes, while the average volume of cutslope failures was only 126 m^3 (maximum volume = 730 m^3). Many of the smaller cutslope failures were trapped on the road prism (Fig. 7), while most of the landslides in fillslopes continued down the steep hillside unimpeded to the Yong Chun River tributaries (Fig. 2b). The higher volumes of fillslope failures include scouring of the lower slopes as the mass movements proceeded to the stream. No fillslope landslides were inventoried in the moderately severe erosion section (0.75 km in length). Total landslide erosion rates along the moderately severe, severe, and very severe monitored sections of the road were about 155, 24, and 210 times greater than the estimated rates of dry ravel (Fig. 6), yet by erosion standards for degraded lands in Southeast Asia (Sidle et al. 2006), the ravel rates in the severe and very severe road sections would be considered quite high.

It is clear that translational fillslope landslides generate more sediment loss and deliver more sediment to streams than all other mass wasting processes combined; however, these failures are more spatially limited compared to other erosion and mass wasting processes. One reason for the high amount of sediment delivery is that once these fillslope failures

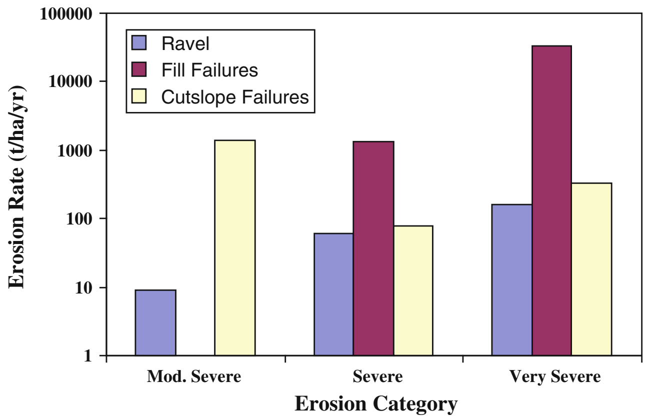

Fig. 6 Landslide erosion from cutslopes and fillslopes and ravel erosion in three different categories of erosion severity along the Weixi–Shangri-La road

Fig. 7 Small cutslope failures trapped on the road prism

initiate on steep slopes, they move directly to the tributaries of the Yong Chun River and often entrain additional sediment along the way. It was not possible to assess how many of the fillslope failures were exacerbated by concentration of road drainage, although it appears that most were merely attributable to the placement of loose and unstable fill on steep sideslopes. While the cutslope failures can be more deadly (i.e., the one that killed six people traveling by in a minivan in summer 2006), at least a portion of the sediment generated by such landslides is trapped on the road surface (Fig. 7), unless, of course, the entire road prism fails. Almost all of the cutslope failures were related to excavation and oversteepening of the hillsides. No road-related slope failures appear to initiate directly within the prism (traveling surface) along the Weixi–Shangri-La road.

Extrapolating these rates of mass wasting to the 24.5-km stretch of the Weixi–Shangri-La road provides an estimate of landslide erosion losses and delivery rates to streams in this headwater system. Based on the estimated contributions from different erosion categories of the road, mass wasting rate was 9,610 t ha^{-1} year^{-1} during the first 4 years after road construction. This rate is more than an order of magnitude higher than the highest landslide rate ever previously documented in careful investigations along roads (summarized by Sidle and Ochiai 2006). To put this into perspective, the average mass wasting rate along the Weixi–Shangri-La road during the first 4 years after construction was 185 times higher than the average landslide erosion along forest roads constructed in highly unstable terrain based on numerous studies in western USA in the 1960–1980 s (summarized by Sidle and Ochiai (2006)). This average value of road-related erosion in western USA (about 52 t ha^{-1} $year^{-1}$) was sufficiently high to convince forest policy makers to essentially terminate logging on Federal lands in this region in the 1980s.

4.3 Surface erosion

Sheet wash and rill erosion from cutslopes dominated surface erosion rates, especially in severe and very severe erosion categories where cutslope erosion was 2.5 and 4.4 times higher, respectively, than fillslope erosion (Fig. 8). Even the surface erosion rates estimated from the cutslopes (33 t ha^{-1} $year^{-1}$) and fillslopes (58 t ha^{-1} $year^{-1}$) of the moderately severe erosion road section are comparable to erosion rates from highly disturbed lands in Southeast Asia (Sidle et al. 2006). The surface erosion rates in the severe and very severe erosion categories (218–1,719 t ha^{-1} $year^{-1}$) are higher than from most any land uses and secondary roads in Southeast Asia (Sidle et al. 2006) (Fig. 8). Gulley erosion was concentrated in the severe erosion section (Fig. 4) and was the distinguishing feature separating the severe erosion category from the moderately severe category where no gulley erosion was noted. The fact that very little gulley erosion was noted in the very severe erosion category could have been masked due to the reworking of fillslopes by landslides and ravel (Fig. 2b).

Considering the entire 24.5-km section of the Weixi–Shangri-La road, average surface erosion from all sources was 765 t ha^{-1} $year^{-1}$. While this value is only about 7% of the total erosion (including landslides and ravel) from the road, it exceeds all values of road and trail erosion reported from even the most disturbed logging skid trails in the tropics (Sidle et al. 2006). This is a bit unexpected because erosion only occurs on cut- and fillslopes; no erosion would occur from the paved road surface. The high surface erosion

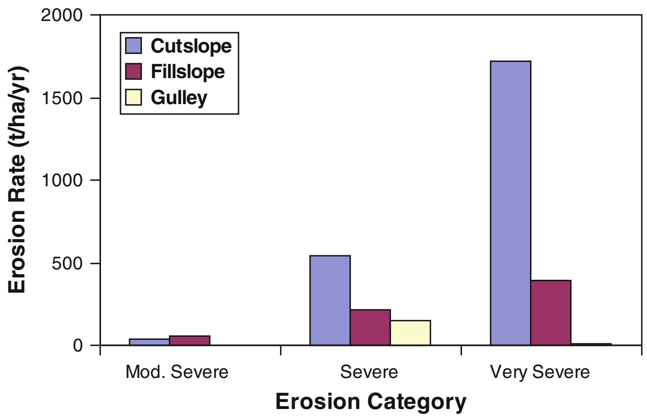

Fig. 8 Surface erosion estimates from cutslopes and fillslopes and gulley erosion in three different categories of erosion severity along the Weixi–Shangri-La road

levels are attributable to the long, unvegetated fillslopes and especially the long and oversteepened cutslopes.

4.4 Aggradation of stream channels

Based on our qualitative field observations, large amounts of debris and sediment have accumulated in the stream channels adjacent and downgradient from the newly constructed road. This sediment appears to have originated from landslides, debris flows, dry ravel, and surface wash from fillslopes along the road and to a lesser extent from cutslopes. Fresh sediment was observed in channels in the catchment that were downslope of the new road (Fig. 9a), whereas adjacent channels of similar catchment size, gradient, and baseflow discharge (<1 $m^3 s^{-1}$) that were not impacted by roads had significantly less sedimentation (Fig. 9b). In some cases, channel aggradation damaged cultivated lands in the floodplain.

The deposited sediment in these headwaters is subsequently transported to the main stem of the Mekong River (Fig. 10); however, stream morphology, including the lack of scour evidence in floodplain deposits, suggests that episodic flooding events, which transport the majority of the sediment and debris in the impacted tributaries, have not occurred in this area since the road construction began in 2002. The absence of major flooding in this headwater system during the 4 years following road construction was corroborated by local residents. Based on these observations, future evolution of channel morphology may occur in one of two ways with very different hazard implications. In the first scenario, the level of peak flows will not be sufficient (i.e., energy limited) to transport the bulk of the aggraded sediment and debris out of the impacted tributaries, and progressive partial transport of sediment will continue for the next few centuries. In a second

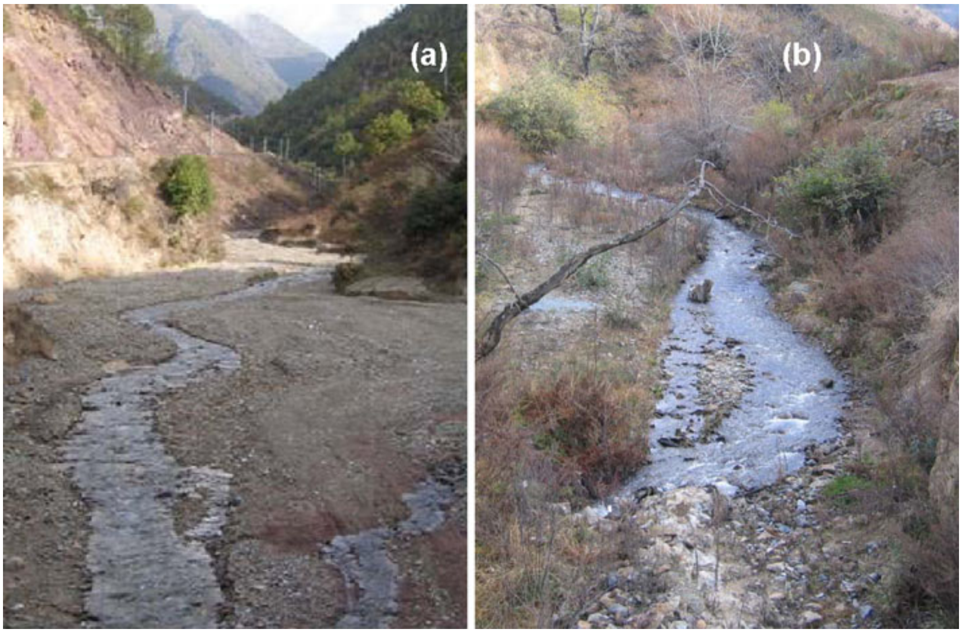

Fig. 9 **a** Aggradation of the stream in the vicinity and downstream of the road; **b** similar size stream with similar gradient and baseflow discharge in an adjacent catchment with no significant road influences: little sediment aggradation occurred in this channel. Both stream reaches are shown in Fig. 1

Fig. 10 The confluence of the Yong Chun River with the Mekong River (see Fig. 1 for location); debris and sediment transported from the tributary form a small delta near the confluence

less likely scenario, a major flooding event will provide ample energy to transport the majority of the accumulated sediment and debris resulting in a large debris flood or hyperconcentrated flow (e.g., Slaymaker 1988; Yumuang 2006; Jakob and Weatherly 2008). Quantitative investigations into sediment and debris transport in this channel together with probabilistic assessment of flood frequency are necessary to address this environmentally important question.

4.5 Comparison of road-related erosion with other sources

Comparison of road-related sediment that is delivered to river channels with sediment from the greater landscape, where scattered agriculture and other human activities persist, is difficult because of problems with assessing sediment delivery related to widespread land uses. Based on our observations in this catchment, as well as numerous surrounding areas, sediment delivery to channels from widespread land use is relatively minor because many of these activities occur on gentler slopes or in areas where slope breaks and/or heavily vegetated buffers reside downslope. It is well known that erosion estimates from managed plots are typically much higher than from similar land use distributed throughout catchments because of opportunities for sediment deposition prior to reaching channels (e.g., Sidle et al. 2006). Mountain roads, on the other hand, are more direct vectors of sediment to channels. Given a conservative estimate that 80% of the road-related landslide sediment and surface erosion was delivered to the river system in our study area, this would still be about 8,300 t ha^{-1} year^{-1}, orders of magnitude higher than reported erosion rates from agricultural activities in Asia (Sidle et al. 2006).

For the reach of the Yong Chun River affected by the Weixi–Shangri-La road, a contributing area of approximately 125.5 km^2 exists on the northeast side of the river (Fig. 1). Even though the road occupies less than 0.4% of this catchment area (about 0.5 km^2), it is responsible for the bulk of the sedimentation. Field observations revealed that the much of the catchment was covered by brush with scattered trees and interspersed with various small-scale agricultural activities. Based on data from Southeast Asia as well as our field observations, erosion from such land cover and hillslopes would not be more than 3.5 t ha^{-1} year^{-1}. Assuming a rather generous delivery rate of 50% from these remote sources, the average annual sediment contributed to the river system from the non-roaded portions of our study area would be about 21,960 Mg. This compares to about 415,000 Mg delivered the river annually by combined surface and mass erosion—nearly 19 times the sediment delivery from the remaining 99.6% of the catchment area on the northeast side of the river. This comparison does not include any erosion or landslides emanating from the older road. Since the surveyed road is newly constructed and landslide erosion is typically higher during the first few years following construction, these rates will likely decrease with time. Nevertheless, the deep cuts into unstable bedrock and the loose material on steep fillslopes will provide active sources of sediment for years to come.

4.6 Summary, conclusions, and recommendations

Both the surface erosion and especially the landslide erosion rates estimated along the Weixi–Shangri-La road during the first 4 years after construction exceeded any values ever reported for mountain roads. These unprecedented rates of landslide erosion (1,410–33,450 t ha^{-1} year^{-1} depending on the erosion severity category of the road) are particularly significant because this is a paved mountain road. Unfortunately, similar erosion/sedimentation scenarios appear to be occurring throughout the northern Yunnan region, especially related to the construction of unpaved mountain roads in the other headwater reaches of the Mekong River as well as in headwaters of the Salween and Jinsha Rivers. During our excursions through this area in October 2006 and December 2007 and based on our detailed observations along the Weixi–Shangri-La road, we conclude that a large proportion of the direct sediment contributions into these headwaters is attributable to road-related erosion, predominantly landslides.

The most problematic source of sediment, especially related to delivery to channels, is fillslope failures. It appears that waste rock and soil was simply pushed onto steep sideslopes during road construction lending this material highly susceptible to sliding-type failures, which are easily routed into the headwaters. By incorporating and compacting this soil and rock material into the road prism or hauling it off to more stable sites (i.e., end hauling), many of these fillslope failures could have been prevented. Moreover, the location of the road was not optimally considered. Long stretches of road were excavated through terrain where long, steep cutslopes were required. These cutslopes produce substantial landslide erosion, persistent ravel, and high levels of surface erosion in all erosion categories. Much of this cutslope erosion was likely redistributed to the fillslope and eventually to the channel because sediment from smaller (nuisance) landslides along cutslopes was physically pushed downslope or transported by overland flow. The bulk of the mass of larger cutslope landslides was redistributed downslope of the road during the failures. Large cutslope landslides, while not as numerous as large fillslope landslides, have already claimed the lives of six travelers along this road. This history does not bode well for future risk along this highway as traffic increases. The incidence of large and damaging cutslope landslides appears rather commonplace along recently excavated mountain roads in this region of northwestern Yunnan where bedrock has been sheared, folded, and fractured during tectonic uplift and past seismic activity.

Given the high levels of sediment being rapidly introduced to headwater reaches of these northern Yunnan rivers, it begs the question as to what the off-site and downstream impacts will be. Nearly all the steep land area between the road failures and river channel is rendered useless—both from productivity and from safety perspectives. The larger-scale impacts of road-related landslides and severe erosion include the interaction of sediment with downstream water bodies and natural resources. One scenario is that the sediment will accumulate in these headwaters and be progressively transported downstream through other poorer nations of Southeast Asia. Such sedimentation is occurring, at least to some extent, and includes issues such as the alteration of channel morphology, which affects the conveyance capacity of rivers and the extent of the floodplain, and the possible transport of pollutants adsorbed on fine sediments (e.g., Zong and Chen 2000; Owens et al. 2005). Additionally, there is a risk of water quality and aquatic habitat deterioration (e.g., Sidle and Ochiai 2006; Bu et al. 2010). Another possibility is that the accumulating sediment in these headwaters will be suddenly mobilized in the future during an episodic flood. The possibilities of such cumulative and long-term disasters need to be carefully investigated in mountainous regions of Yunnan where streams are receiving such high levels of landslide erosion. Such assessments need to guide the future need, development, and location of mountain roads in this unstable terrain.

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ANNEX 2

Mr. Danny Hagans & Dr. Bill Weaver, "Evaluation of Erosion, Environmental Impacts and Road Repair Efforts at Selected Sites along Juan Rafael Mora Route 1856 in Costa Rica, Adjacent the Río San Juan, Nicaragua," July 2014

Evaluation of Erosion, Environmental Impacts and Road Repair Efforts at Selected Sites along Juan Rafael Mora Route 1856 in Costa Rica, Adjacent the Río San Juan, Nicaragua

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July 2014

I. Introduction

Numerous locations along Route 1856 between Mojon II and the Rio San Carlos are in a disastrous state of disrepair and exhibit severe instability since road construction began in 2011. Most of the most seriously eroding and most neglected road locations are along the 25 km of Route 1856 where efforts to construct the road have occurred across steep hill slopes in close proximity to the Rio San Juan (Figure 1). A review of paired oblique aerial photographs taken from helicopters in October 2012 and May 2014 illustrates the widespread, ongoing and persistent erosion occurring along portions of the route from a combination of landslide, fluvial (gully) and surface erosional processes (Appendix A: 23 sheet erosion inventory 11x17 along river). These photographs, when viewed in conjunction with the December 2013 high-resolution satellite imagery, clearly document continued large scale and active erosional processes occurring on some road cuts, fill slopes and at several very large stream crossings along the route where the road should be classified as unsafe for public and commercial use.

Most all road reaches and stream crossings we observed are exhibiting varying degrees of active, ongoing erosion as a result of inadequate planning (location), design, construction, erosion control, and maintenance practices. The extent of observed erosional impacts is extraordinary in scale, especially considering the very average rainfall patterns that the road has experienced over the three year period since construction began (see Kondolf, 2014). Immediate emergency actions are needed to curtail ongoing and future erosion and sediment delivery to the Rio San Juan, and these emergency actions should be of the highest priority to all parties involved.

Based on our extensive experience in controlling and normalizing forest, ranch and rural road erosion processes to protect water quality on both public and private road systems, we recommend the Costa Rican government immediately undertake the following mitigations and emergency erosion and sediment control measures. The measures include those designed to mitigate and prevent damage from 1) fill slope instability and mass wasting, 2) stream crossing erosion and failure, 3) cut bank instability and mass wasting, and 4) surface erosion from quarries, road surfaces, cut banks, fill slopes and other bare soil areas. These measures are those that are required, at a minimum, to control ongoing impacts and reduce the risk and magnitude of future sediment delivery to the Rio San Juan from the existing road work, as well as to provide for a safe road for future commercial and public use. Their implementation of these measures should be overseen by qualified engineers and geologists specifically trained and experienced in road restoration, road reconstruction, and erosion control.

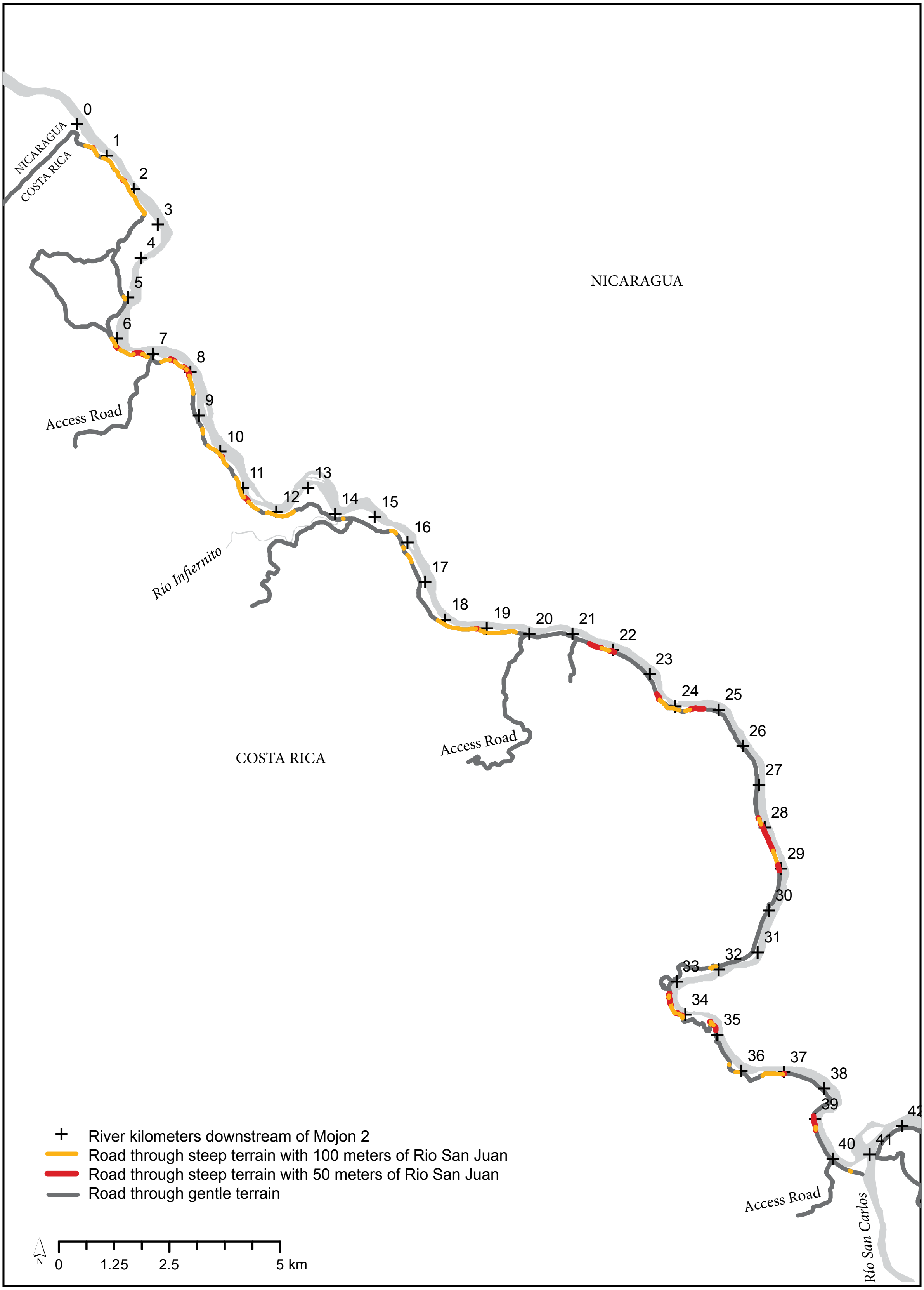


Figure 1. Map highlighting road through steep terrain and within close proximity to Río San Juan where relocation possibilities should be considered

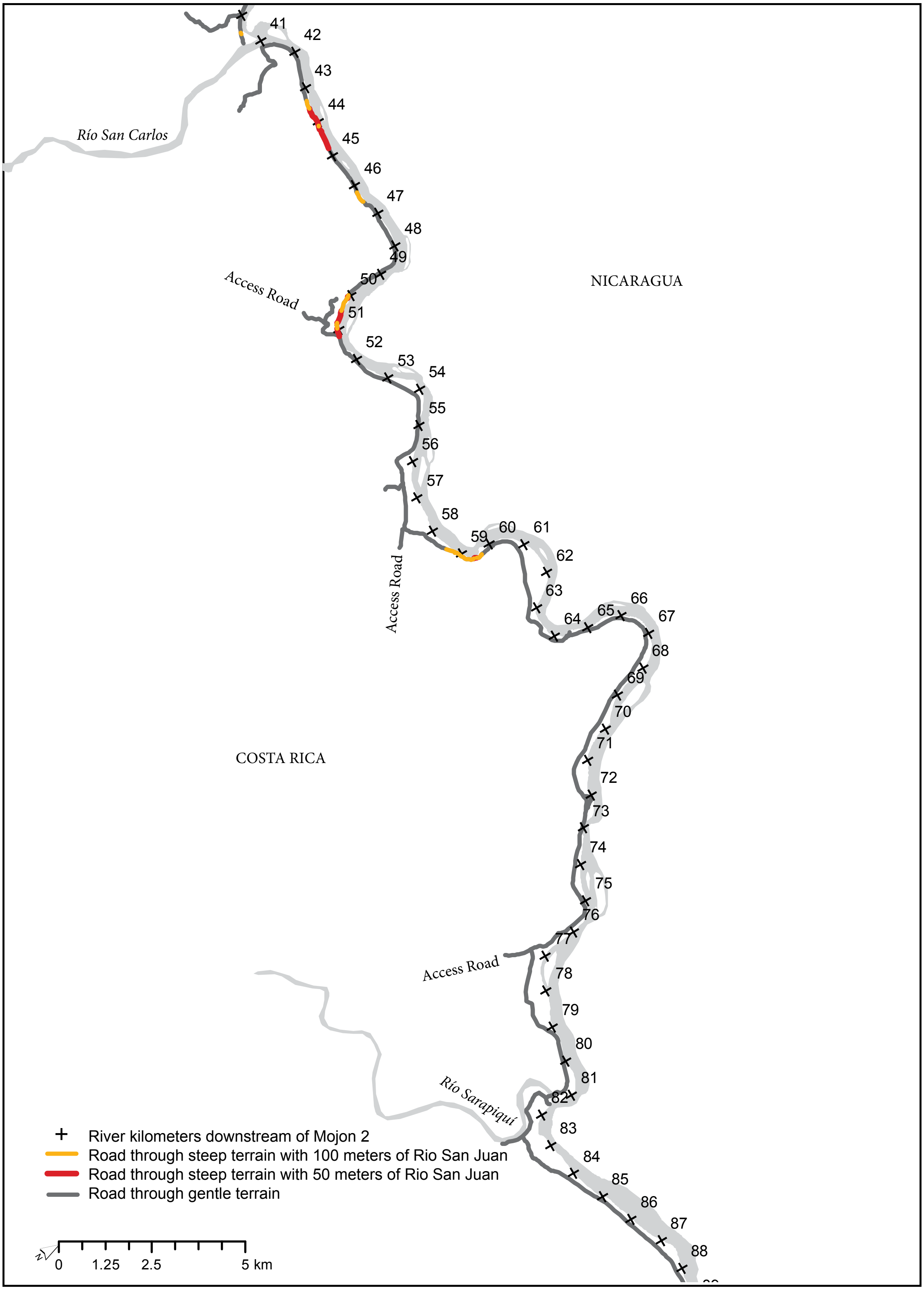


Figure 1. Map highlighting road through steep terrain and within close proximity to Río San Juan where relocation possibilities should be considered.

II. Severe Erosion at Stream Crossings Documented by Time-Sequential Aerial Imagery

The following examples at several actively failing and eroding hill slope, cut bank, fill slope and stream crossing areas along the route upstream of the Boca San Carlos illustrate the severe inadequacy and nearly total lack of erosion control efforts at failing road locations over the last 2 years since we first visited Route 1856. It also demonstrates significantly higher erosion rates and volumes of erosion than previously claimed by Mendes and Astorga (2013). In addition, the lack of any design and construction standards along the route has resulted in constructing extremely unstable road reaches that will be subject to continuing and future slope failures and erosional impacts to the Rio San Juan for decades to come. In their present state of disrepair, these sections of road are extremely unsafe for commercial and/or public transportation, and will require substantial financial resources to either properly close (i.e. put-to-bed or decommission portions of the route) or redesign and reconstruct these specific road sections, as well as many other similar locations we have observed along Route 1856, in order to be suitable for public use, as well as protect Nicaraguan resources.

A. Three Stream Crossings along Route 1856: Problems and Recommended Solution

Figures 2, 3 and 4 illustrate three (3) examples of extremely poorly designed, constructed and maintained stream crossings along Route 1856 in the area known as Las Crucitas (from approximately 17.5-19 km downstream of Mojon II). Photographs were taken comparing the sites over the 20 month timeframe between October 2012 and May 2014. Each of the three stream crossings exhibit a combination of active gully erosion and landsliding, progressive embankment and cut bank failures, widespread surface erosion from the easily visible bare soil areas, as well as very sparse, poorly applied and ineffective erosion control measures applied to prevent or control ongoing erosion. Given the visible high level of instability clearly documented in the photographs, and the failure to follow even basic road engineering and construction principles, it is clear to us that few, if any, of the fills were properly compacted. With this lack of care and attention to basic design and construction principles for stream crossing construction, and based on visual evidence, it does not appear that stream crossing drainage structures (e.g., culverts) were properly designed and sized for large, infrequent flood flows, or that they were installed and located correctly within the fill. Even by our remote visual inspection, culverts clearly appear unreasonably small for the drainage basins they are supposed to drain, and are often placed high in the fill with extensive erosion having already occurred where they release stream flow onto the new, unprotected, erodible fill materials. Workmanship on critically important stream crossings right next to the Rio San Juan, like the ones in these examples, is unreasonably poor and unprofessional. They were either poorly designed or poorly constructed, or both. Regardless, the impacts to the Rio San Juan have been significant and threaten to be even larger in time.

At each of the stream crossings in these three examples, we have graphically outlined (diagrammed) the estimated dimensions of fill material placed (bulldozed) into and over the tributary stream channels when the road was constructed to provide for each road crossing. We have also estimated the dimensions of the fills and determined these 3 stream crossings contain from a low of 12,000 m^3, to a high of over 44,000 m^3, of fill material. Estimates of erosion during the past 20 months at these three stream crossing range from 7% to over 20% of the constructed fill volume, and the images suggest minimal efforts and largely ineffective methods to prevent continued and future erosion. The presence of very visible, massive deltas that have formed in the Rio San Juan, and the severely aggraded downstream tributary channels below these stream crossings, confirms the ongoing impact to Nicaraguan territory.

Because of the disastrous condition of these sites, the volume of the un-compacted fill involved, the enormous challenges that would be faced in attempting to stabilize these crossings, and the extreme proximity to the Rio San Juan (the fill edges are mostly within 100m of the river bank), we recommend that this section of Route 1856 be re-routed to an alternative, inland route to the south. The precise extent of the section that should be re-routed and the new route should be determined by ground inspection and surveys conducted by qualified experts. Based on information available to us, the entire section of Route 1856 encompassing these three sites should be re-routed, and as recommended by the Environmental 'Diagnostic' Assessment (EDA) submitted by Costa Rica, Route 1856 should be re-routed downstream of Rio Infiernito, which implies moving the entire section from approximately river km 14 to 20 (i.e., from about 14 km to 20 km downstream of Mojon II).

Our recommendation that this part of the road be moved inland is consistent with that of the EDA (Annex 10), which included recommendations for environmental measures to be implemented in response to "occurrence of landslides and slope erosion affecting the forest borders of the road." The EDA recommended measures include, "to evaluate the technical possibility of modifying the route designated for Route 1856 at the point called Infiernillo [sic] to include the use of local roads built on less sloping terrain, tracing the road some km. to the south, where there are open areas and settlements with more favorable topographic conditions." (p. 147 of the EDA, Annex 10 to the Costa Rican Counter-Memorial.) The recommendation is repeated in the Conclusions section of the EDA: "Evaluate the technical possibility of modifying the Route design at the point of Infiernillo [sic] to follow local roads built previously, deviating for some km. to the South, where there are settlements and open areas with topographic conditions that are more favorable to this type of project." (p. 162 of the EDA, Annex 10 to the Costa Rican Counter-Memorial.)

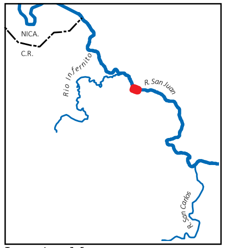
In addition to locating new and less environmentally destructive alternative routes, it will be necessary to stabilize (i.e. properly decommission) the partially constructed sites that will be abandoned. This is discussed for each of the three stream crossings below, and for two sites of failing cut and fill slopes.

Figure 2. Severely Eroding Site 9.4

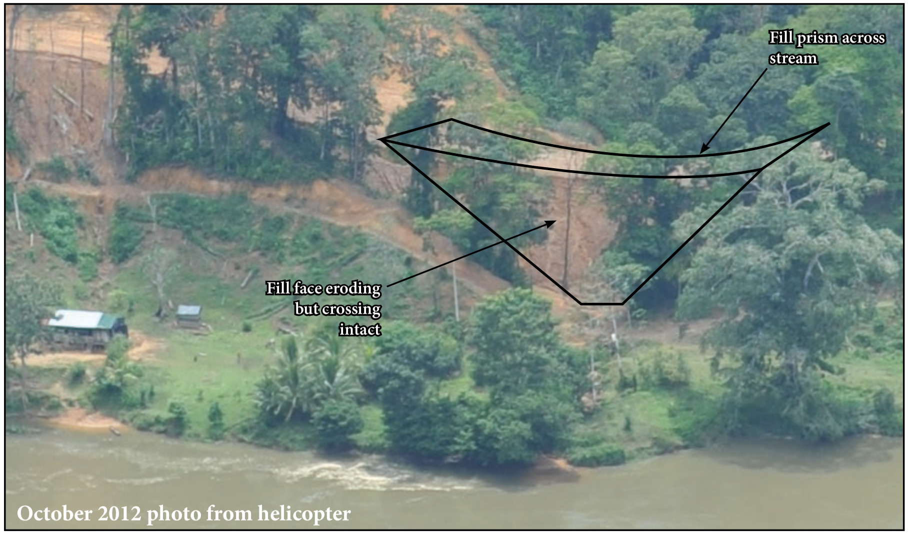
Road fill crossing located 18.0 km downstream from Mojon 2.

Total fill volume of the original crossing is approximately 22,000 m^3. A large portion of the crossing was washed out between October 2012 and December 2013, as evidenced by December 2013 satellite imagery. The failed road fill was subsequently refilled before May 2014 photos. Using GIS measurements from December 2013 high-resolution satellite images and an estimate average erosion depth of 3m, total estimated sediment eroded from just the fill failure is 1,722 m^3. This does not include additional sediment from sheet, rill, gully, and landslide erosional processes, and continued erosion from the attempted repairs.

Mende & Astorga (2013) "worst-case" annual yield for this fill prism (T-068a,b) = 455 m^3/yr, which includes all sheet, rill, gully, and landslide erosion for the fill prism.



Location Map



Sediment delta from eroded fill and cut slopes (March 2014).

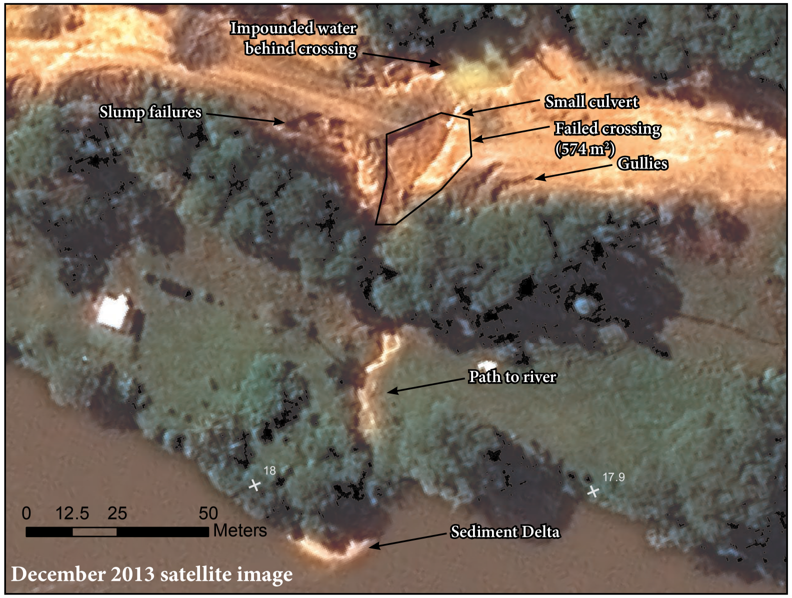
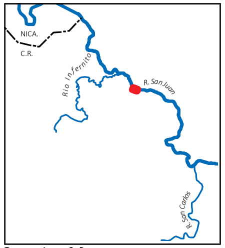


Figure 3. Severely Eroding Site 9.5

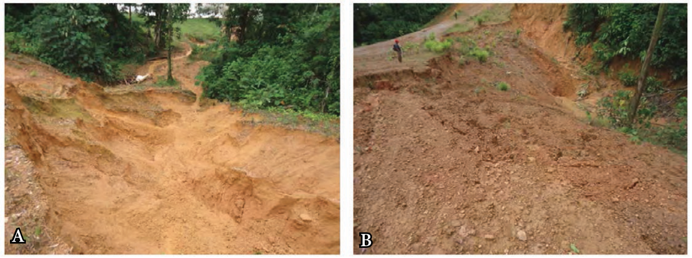
Road fill crossing located 18.1 km downstream from Mojon 2.

Total fill volume of the original crossing is approximately 12,000 m^3. A large portion of the crossing was completely washed out since October 2012, as evidenced by December 2013 satellite imagery, and was subsequently refilled and before May 2014 photos. Using GIS measurements from December 2013 high-resolution satellite images and an estimate average erosion depth of 4m, total estimated sediment eroded from just the fill failure is 2,860 m^3. This does not include additional erosion from sheet, rill, gully, and landslide erosional processes, and continued erosion from the attempted repairs.

Mende & Astorga (2013) "worst-case" annual yield for this fill prism (T-070a,b) = 372 m^3/yr, which includes all sheet, rill, gully, and landslide erosion for the fill prism.



Location Map



Gully on fill face (A) and erosion on backside of fill prism (B) (from Mende & Astorga 2013, p43).

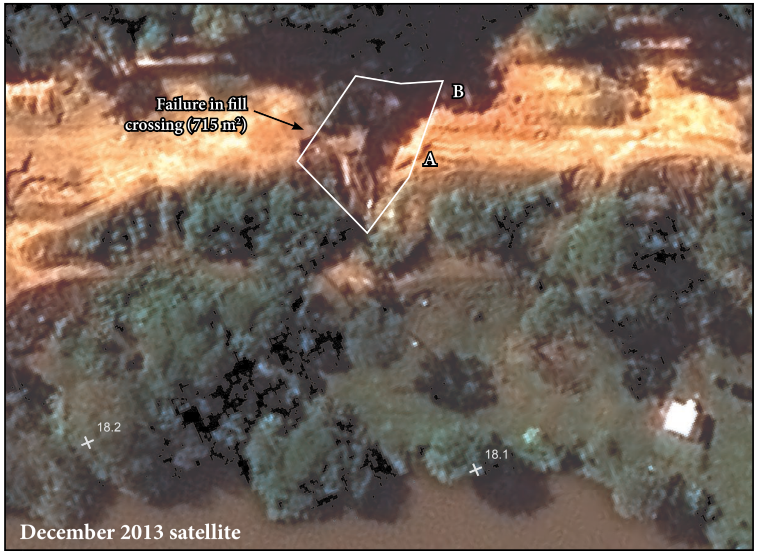


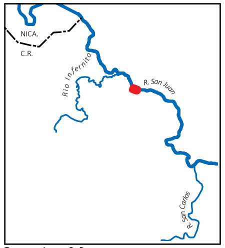
Figure 4. Severely Eroding Site 9.6

Road fill crossing is located 18.2 km downstream from Mojon 2.

Total fill volume of the original crossing is approximately 44,000 m^3. The 3 main gullies on the front side of the fill slope are labeled A, B, and C. Gully areas measured in GIS from December 2013 0.5-m resolution orthorectified satellite imagery, with a conservative estimate of 3m average gully depth, total estimated fill eroded from the three gullies is:

A = 2,100 m^3 B = 2,100 m^3 C = 2,400 m^3
Total eroded sediment from 3 gullies = 6,600 m^3

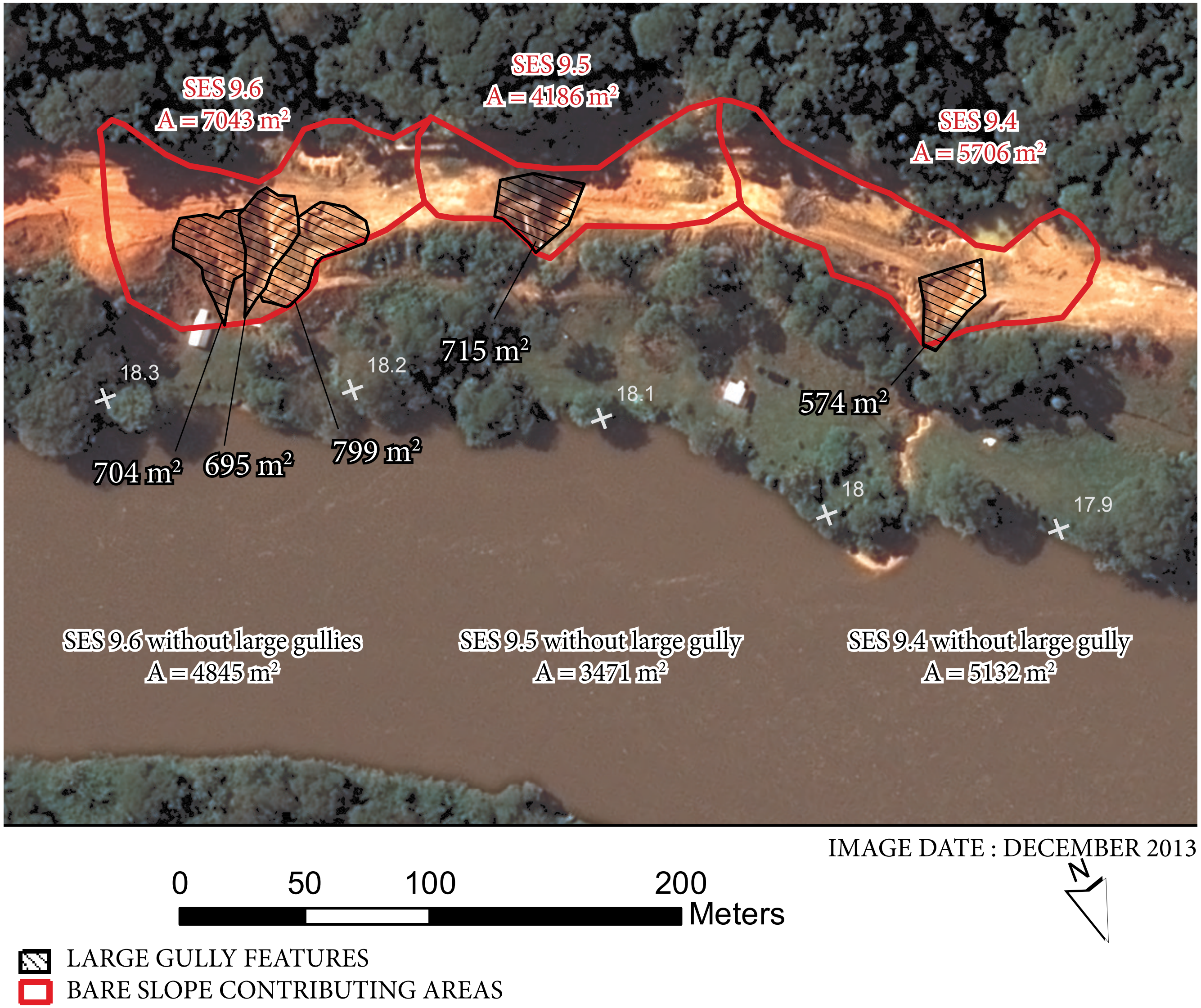
Mende & Astorga (2013) "worst-case" annual yield for this slope (T-072a/b) = 662 m^3/yr, which includes all sheet, rill, gully, and landslides erosion.



Location Map

Gullies B and C (from Mende & Astorga 2013, p44).

Figure 5. Delineation of bare slope contributing areas that are actively eroding at sites 9.4, 9.5, and 9.6.



B. Stream Site 9.4 at RSJ River 18 km

Figure 2 documented the upstream-most of the three large stream crossings at Las Crucitas, designated as Severe Erosion Site 9.4 in our inventory of severely-eroding sites (Appendix A), and identified as crossing 68 by Mende and Astorga (2013, Annex 6). This is located 18.0 km downstream of Mojon II. The volume of fill dumped in the tributary channel during road construction is estimated at 21,900 m^3. The oblique October 2012 aerial photograph illustrates the poorly constructed, unstable fill, and the absence of any serious effort to apply appropriate, effective erosion control measures at and near the crossing. The fill slope clearly displays rapid deformation following initial construction work and the road and adjacent cut and fill slopes lack any attempt at stabilization or erosion control. Both road approaches to the crossing along Route 1856, and the associated high cut banks, can be assured to be delivering eroded sediment from the visible and unprotected bare soil areas by surface erosion, rill erosion, and gully erosion processes. Most all these sediments are transported to the stream crossing since it is the topographically low point seen in the images. Finally, the smaller road that has been constructed across the hill slopes below Route 1856 also appears to be a source of uncontrolled surface erosion, rill and gully erosion that is also being transported directly to the same natural stream channel, and then into the Rio San Juan. As a result, this tributary deposited a large delta of eroded sediment in Nicaragua's Rio San Juan.

In the December 2013 satellite image, one can see the magnitude of the combination of gully erosion and landsliding that is uncontrolled and ongoing through and near the axis of the stream crossing fill (Figure 2). A large area of ponded water (a small lake) has formed at the inside edge of the road (Route 1856), clearly suggesting the culvert was either significantly undersized to convey even average rainfall events, or was poorly installed high in the fill, or both. The downstream natural tributary channel is visibly impacted by recent deposits of transported and stored sediment. In addition, the delta of eroded sediment that formed in the Rio San Juan has rapidly grown in size. In spite of the clearly visible ongoing erosion and downstream damage to the Rio San Juan, no apparent efforts to prevent or control erosion, landsliding (fill slope and cut slope failures), or potential future erosion at the crossing site had been undertaken between October 2012 and December 2013. If any interim erosion control or slope stabilization measures were attempted, they were obviously inappropriate and inadequate for controlling the type and magnitude of erosion that has occurred and continues to occur, and are totally ineffective at protecting the Rio San Juan immediately downslope. There was no significant, visible attempt to limit impacts to the Rio San Juan.

In the May 2014 oblique photograph of the same site (the third photo in the sequence), the large gully through the stream crossing present in the December 2013 image has been partially filled to permit limited vehicle passage on the road. A large body of ponded water is still visible upstream of the road, suggesting the culvert now in place (whether the remnants of the original culvert or a replacement culvert) is plugged and deeply buried by sediments from the collapsing, rapidly eroding, and failing stream crossing fills. No Costa Rican efforts are visibly apparent that might have effectively stabilized the failing, un-compacted stream crossing fills. Likewise, no visible efforts have been implemented to properly install adequate stream crossing drainage structures (culverts or bridges), or to address uncontrolled runoff and erosion from all the visible bare soil areas. The site is a construction disaster that has not been treated or stabilized, and it clearly threatens to fail catastrophically if a significant storm causes the ponded tributary to overtop the fill again, thereby eroding a larger portion of the entire stream crossing fill and delivering up to 21,900 m^3 of sediment (equivalent to 2,740 8-m^3 dump truck loads) directly into the Rio San Juan (see Figure 2: outlined fill prism on 2012 helicopter photo). The delta in the Rio San Juan appears significantly larger in the 2014 photo than in the 2012 photo. While this is partially due to the May photo being taken at lower water (when more of the delta would be exposed and visible), the change almost certainly reflects the growth of the delta as well, growth that will continue over the next rainy season, since no concerted efforts have been undertaken to properly redesign and reconstruct the crossing, and thereby to eliminate the active erosional processes occurring at the site.

Using scaled measurements from the oblique photographs and GIS measurements from the December 2013 vertical satellite image, we estimate that sediment production from just the gullied and failed stream crossing fill is 1,722 m^3/yr. On Figure 5 we have drawn the remaining approximate contributing area in m^2 (minus the primary gully/failed crossing area) that drains erosional products to the axis of Site 9.4's stream channel, and estimate the area to be 5,132 m^2. Using the average of the average rates for cut slope and fill slope erosion reported by Mende and Astorga (2013, Annex 6, Table 7) for landslide, gully and rill erosion (i.e. average rill = 0.205 m + average gully = 0.48m + average landslide = 0.99)/3 = 0.558 m/y), and assuming a combination of rill, gully and landslide erosion is occurring on 40% of the defined contributing area, approximately 1,145 m^3/yr of additional rill, gully and landslide erosion is occurring at Site 9.4 (Figures 2 and 5). Applying the average of Mende and Astorga (2013, Annex 6, Table 7) estimated surface erosion rate of 0.095 m for cut slopes and 0.24 m for fill slopes = 0.168 m/y to the remaining 60% of the bare soil contributing area visible at Site 9.4 (Figures 2 and 5), approximately 517 m^3/yr of material is being produced by surface erosion processes annually at Site 9.4.

Combined, we estimate Site 9.4 has produced a minimum total of 3,384 m^3/yr of eroded material from the main axial gully as well as via sheet, rill, other gully and landslide erosion processes occurring on the adjacent bare soil area (from within the contributing area shown on Figures 2 and 5). A significant portion of this erosion volume has been delivered downslope to the Rio San Juan. Our estimate of 3,384 m^3/yr is significantly higher than Mende and Astorga's (2013) reported estimate of total sediment production from this site of 455 m^3/yr (Figure 2), which we believe to be a significant under-representation of the actual erosion documented in the imagery.

The fact that water is ponded upstream of the crossing indicates that whatever culvert was originally installed in the crossing fill, is now blocked by sediment or debris. The stream crossing fill consists of loose earth, dumped in the stream valley. It is not engineered to function as a dam. The presence of ponded water (especially after rains when the water level rises) will again cause the stream to overtop the inside edge of the road, resulting in flow through the axis of the large gully within the unprotected fill slope, triggering a renewed bout of uncontrolled erosion that could ultimately result in the entire fill to wash out, and if this occurs, a significant percent of the entire 21,900 m^3 stream crossing fill is likely to be transported downstream towards the Rio San Juan, which is only 100 m away.

The absence of any meaningful efforts at controlling or minimizing ongoing and future erosion at the site over the 20 month period demonstrates a complete disregard for resource protection. The scale of Costa Rica's underestimation of erosion at this site is indicated by the fact that the site's 21,900 m^3 of future potential erosion is itself equivalent to nearly 60% of the total annual sediment production Costa Rica estimates is delivered from the entire 108-km stretch of road along the Rio San Juan (Mende and Astorga, 2013, Annex 6, p. 402).

Recommended Solution

As noted above, this section of road should be moved to a less-steep, inland location. While moving the road will provide a better situation for future road stability and erosion management, there is the problem of how to manage the erosion from the slopes above the river at Las Crucitas along the current road alignment. In order to properly decommission this stream crossing, the following steps are required:

A. As soon as weather and soil conditions permit, mobilize heavy earthmoving equipment to excavate the entire mass of fill dumped in the tributary stream valley at this stream crossing, which we estimate from high-resolution satellite imagery and oblique aerial photography to be 21,900 m^3 (see Figure 2: the outlined area on the 2012 helicopter photo). Removal of the road-stream crossing should consist of:
    i. excavating and removing all the stream crossing drainage structures (i.e., the plastic-pipe culverts),
    ii. excavating all the fill materials out of the stream crossing so as to "exhume" the original, natural channel bed, re-establish the natural thalweg channel gradient and 100-year return interval flood flow width, and provide stable side slopes that either mimic the original natural stream side slopes or have a maximum 2:1 stable side slope angle,
    iii. seed and mulch all bare exposed soils for temporary erosion control, and
    iv. permanently replant all the mulched areas with a mix of native shrubs and trees at a spacing of 1 plant every 3 m^2.

B. Identify a stable spoil disposal location(s) situated on flat ground that is at least a 100 m distance from the Rio San Juan or its tributaries, and upon which vegetation can be established to stabilize the spoil material, such that the spoils will not be eroded and transported to the river. Once the disposal site(s) is selected, the existing Route 1856 can be temporarily repaired for access by heavy equipment and used to transport material excavated from the stream crossings during the decommissioning process to the spoil site. If the spoil material is of suitable quality, some of it could potentially be used as road sub-base for the re-located Route 1856, but it is essential that its properties be tested by qualified experts to avoid the pervasive problems of improper use of substandard materials documented along Route 1856 by CFIA (2012) and LANNAME (2012).

C. End haul with dump trucks the excavated spoil materials to the identified stable disposal site(s).

D. Stabilize exposed cut slopes by reseeding and planting (where possible given slope conditions), and where indicated by qualified experts, implement other techniques to improve slope stability, such as installing horizontal drains, and/or geotextile and geo-grid materials.

E. If cut slopes are determined to be significantly over-steepened, it may be necessary to lay them back or terrace them to a more stable angle to reduce the likelihood of cut slope failure. This would require further cutting of the slope and would generate additional spoil material to be removed and safely disposed of. Because of the further disturbance and additional spoil created by laying back the cut slopes, this technique should be implemented only where indicated by qualified experts who have the opportunity to visit the site and conduct the necessary tests of material strength, slope stability calculations, etc. and who determine that the benefits of the action would outweigh its impacts.

F. In addition to the slope-stabilization measures (geo-grid, geotextiles, horizontal drains, and laying-back the slopes), surface erosion control measures should be implemented on each exposed cut slope, at post-construction native hill slopes that have experienced landslides such as the two debris slides located upstream of the stream crossing fill prism shown on the Site 9.5 2014 oblique photography (Figure 3, discussed below), and on native slopes that were buried by sidecast fill and which accordingly have lost vegetative protection. These surface erosion control measures are described below near the end of our report.

G. Removal of this fill material will need to be coordinated with removal of fill from the other two stream crossings (i.e. Sites 9.5 and 9.6) at Las Crucitas, and probably with removal of material from the cut-and-fill-slope erosion at Severe Erosion Sites 8.1 and 8.2, discussed below. These of treatments should be applied at any other stream crossings and fill slopes along Route 1856 recommended by qualified experts where the prudent approach is to decommission the current road alignment and re-route the road farther inland to less erosive terrain (Figure 1).

H. The danger of having heavy trucks using the unstable crossings at Sites 9.4, 9.5, and 9.6 must be taken into account, and the stability of these crossings (after their temporary repairs) should be monitored closely when in use to transport spoils. At the first indications of deformation and instability due to the heavy loads of dump trucks, the crossings will be taken out of service until further temporary repairs/stabilization measures can be performed to insure the safe passage of heavy vehicles until the removal of all stream crossing fill materials and other unstable fill- and cut-slope materials can be safely excavated and exported from the location.

C. Stream Site 9.5 at RSJ River 18.1 km

This series of photographs illustrate the ongoing and dynamic erosional processes occurring at Severe Erosion Site 9.5 (18.1 km downstream of Mojon II), and in its immediate vicinity, over the same 20 month period (Figure 3). On the oblique 2012 photograph (and in ground photo "B"), severe deformation and slumping is visible on both the upstream and downstream fill slope faces almost immediately after construction of the stream crossing. This stream crossing fill failed (eroded) between October 2012 and December 2013, delivering over 2,860 m^3 of eroded sediment to the Rio San Juan (see 2013 satellite image). The cause of this failure was likely a poorly designed (probably greatly under-designed and undersized) stream crossing culvert, combined with native hill slope failures triggered by the initial road construction work.

On the May 2014 oblique aerial photograph, two large landslides are visible on the hill slopes just upstream of the road crossing. These landslides may have caused the stream crossing failure by plugging the culvert, or they may have been triggered by saturation of the toe of the slopes when the new stream crossing culvert plugged and a small lake formed behind the fill. In any event, the plugged culvert caused stream flow to pond, overtop the road fill, and consequently erode a large portion of the fill crossing (clearly visible in the December 2013 satellite image). The road-related and construction-caused landslides and stream crossing failure had a large impact on the Rio San Juan, as all the landslide debris and eroded sediment was transported the short distance to the river. The greatly enlarged delta in the river is clearly visible in the May 2014 photograph (Figure 3).

Once the stream crossing had failed, the May 2014 helicopter photo clearly shows that the stream crossing fill was then simply refilled with bulldozed soil material and a second small replacement culvert pipe was placed at the top of the fill. Now, a lake will again form on the inside of the new road fill and it will fill with water during the next wet season rain until almost reaching the level of the new road surface before it begins flowing into the culvert. Placement of the culvert at the top of the new fill is a totally inadequate, inept and improper design and construction practice, and would not meet any reasonable engineering standard. It is our observation and opinion that few of the culverted stream crossings along Route 1856, especially in the highly sensitive areas we have described, have been sized to accommodate large infrequent storm and runoff events (e.g., the 100-year flood recurrence event is a common design standard for sensitive forest roads and areas), have been constructed with the appropriate materials, or are properly installed within the fill prism. In fact, Mende and Astorga's (2013, p. 399 of Annex 6) classification of the technical status of the 119 partially constructed stream crossings along Route 1856 indicate only 30% of the crossings to be considered "improved or appropriate" (Figure 6, below).

The re-filling of the erosional gully void, and installation of the small culvert at the top of the new fill, provides only temporary vehicular passage at the crossing. No meaningful or permanent efforts have been undertaken to control the significant deficiencies in the design and construction methods employed by Costa Rica at this crossing, or at others along Route 1856. The repair of this crossing has, in fact, made this site an even greater threat that it had been. With the culvert placed at the extreme top of the fill (see Figure 3: May 2014 photo) a lake will develop behind the fill until flow enters the culvert. No downspout or energy dissipation (armor) has been provided at the new culvert outlet (see May 2014 photo) to convey stream flow to the base of the estimated 20 m deep fill slope, so a renewed episode of large gully erosion can be expected to occur at the outlet of the culvert, which will erode the new road fill and again threaten road prism integrity. All the eroded sediment from this poorly designed and constructed stream crossing culvert will be delivered directly to Nicaragua's Rio San Juan.

Additionally, and more seriously, the new road fill that was placed (bulldozed) into the crossing was not designed, engineered or constructed to function as an earthen dam. It will be extremely hazardous to travel across the road during storm events, or anytime water has backed up behind the road fill. The stream crossing fill could easily liquefy and fail catastrophically during or following a storm event. In addition, with a lake or pond at the culvert inlet, floating woody debris brought down by the stream is likely to plug the culvert inlet, thereby causing it to overtop the fill and again washout a significant portion of the stream crossing fill (as shown in the 2013 satellite image). All the eroded sediment from this poorly designed and constructed stream crossing culvert will again be delivered to Nicaragua's Rio San Juan.

Reconstruction of this stream crossing, in the manner that was undertaken, shows complete disregard to the science of road engineering, has caused hazardous conditions for users of the road, and ignores all environmental protection standards. The newly "constructed" road fill at Site 9.5 still exhibits serious instability and the crossing will experience renewed active erosion via a combination of gully and landslide processes, and we predict near complete failure with the advent of future storms that are equal to or larger than the storms the road has experienced over the 20 month period of October 2012 to May 2014. The erosion as observed at these stream crossings results in continuous delivery of sediment to the Rio San Juan during virtually every significant rainfall event, as manifest by the continued growth and enlargement of the fresh sediment deltas visible on the 2014 oblique photo.

Other gullies associated with uncontrolled concentrated runoff from the tall cut banks and road approaches on either side of the stream crossing are visible on the December 2013 and May 2014 images (Figure 3). These gullies serve as effective channels for delivering erosional products derived from the large expanse of bare soil areas visible in the images. The aerial images clearly demonstrate no meaningful efforts by Costa Rica, over the 20 month period, to control ongoing surface, rill and gully erosion from the adjacent exposed bare soil areas present on the road bed, from the tall cut banks and fill slopes, and from the lower smaller spur road that parallels Route 1856, all of which drain erosional products to the stream crossing and then into Nicaragua's Rio San Juan (Figure 3).

We estimate the volume of gully erosion at the stream crossing failure site between October 2012 and December 2013 to have been 2,860 m^3. This does not include the volume of sediment associated with the two large hill slope debris landslides, other landslides and gullies present on the adjacent fill slopes and cut banks outside of the stream crossing fill area, as shown by the black trapezoid on the October 2012 photograph, and surface and rill erosion volumes being generated from the extensive bare soil areas visible in the images. Excluding the area of the prominent gully in the axis of the stream crossing, we estimate the remaining contributing drainage area (i.e. where erosional products will move or be transported to the stream axis) is 3,471 m^2 (Figure 5).

Using the average of the average rates for cut slope and fill slope erosion reported by Mende and Astorga (2013, Annex 6, Table 7) for landslide, gully and rill erosion (i.e. average rill = 0.205 m + average gully = 0.48m + average landslide = 0.99)/3 = 0.558 m/y), and assuming a combination of rill, gully and landslide erosion is occurring on 40% of the defined contributing area, approximately 775 m^3/yr of additional rill, gully and landslide erosion is occurring at Site 9.5 (Figures 3 and 5). Applying the average of Mende and Astorga's (2013, Annex 6, Table 7) estimated surface erosion rate of 0.095 m for cut slopes and 0.24 m for fill slopes = 0.168 m/y to the remaining 60% of the bare soil contributing area visible at Site 9.5 (Figures 3 and 5), approximately 350 m^3/yr of material is being produced within the contributing drainage area by surface erosion processes annually at Site 9.5.

Combined, we estimate that Site 9.5 has produced a minimum total of 3,985 m^3/yr of eroded material from the main axial gully as well as via sheet, rill, other gully and landslide erosion processes occurring on the adjacent bare soil area along Route 1856 (i.e. from within the contributing area shown on Figures 3 and 5). As at Site 9.4, a very significant portion of this erosion volume has been delivered downslope to the Rio San Juan.

Our estimate of the total erosion of 3,985 m^3/yr and sediment delivery to the Rio San Juan at Site 9.5 is significantly higher than the Mende and Astorga (2013) worst case total site erosion volume of 372 m^3/yr (Figure 3). The paired aerial photos and ground based photos in Figure 3 verify this significant under-estimation of annual sediment production at these poorly constructed stream crossing and hill slope contributing areas.

We have no doubt the very unsafe and poorly constructed crossing and contributing drainage area will generate equally large volumes of erosion and sediment delivery to the Rio San Juan as a result of future storms in the very near future and over the coming years. This is especially true since no meaningful or effective efforts appear to have been undertaken to control the accelerated surface, rill, gully and landslide erosional processes that have been triggered by attempts to build Route 1856 in this location. The road construction and reconstruction that has occurred at this site since this section of Route 1856 was initially opened, is completely contrary to modern engineering design and construction standards.

Recommended Solution

As described above, consistent with recommendations of the EDA (Annex 10 of the Costa Rican Counter-Memorial), we recommend this and the other two stream crossings at Las Crucitas be removed completely, as the road should be relocated farther inland to more favorable terrain. The same requirements described above for Severely Eroding Site 9.4 apply to this site: removal of all fill material (approximately 12,000 m^3, the equivalent of 1,525 dump truck loads; see Figure 3: as shown by the fill prism drawn on the 2012 oblique aerial photo), transport of the excavated material to a stable disposal site(s), restoration of the original natural bed of the stream, stabilization of both sides of the stream channel by exhuming the natural angle of the side slopes, and stabilization of the extensive cut slopes through vegetation and geotechnical means, likely including horizontal drain pipes to reduce pore pressures and geo-grids and geotextiles to stabilize the exposed slopes. In some cases, over-steepened cut slopes may need to be laid-back further, a process that will generate additional spoil material to be removed and safely disposed of.

D. Stream Site 9.6 at RSJ River 18.2 km

At Severe Erosion Site 9.6, the October 2012 oblique aerial photograph shows a very large stream crossing fill prism, estimated at 44,000 m^3 in volume, that is undergoing serious deformation and erosion of the downstream fill slope very soon after construction. Presumably the upstream fill slope is also unstable, based on the style and lack of proper design and construction supervision utilized by Costa Rica along the rest of the road (Figure 4). The 2013 satellite image shows three distinct zones of instability that are rapidly developing/evolving on the outer fill slope (Figure 4: see outlined fill prism area on 2012 photo), as well as a severely undersized culvert installed to convey stream flow through the fill prism (October 2012 photo). The culvert that is visible in the October 2012 photograph is poorly located, being far too high in the crossing fill. It is small and placed near the middle of the fill prism (see Figure 4); a practice that is inconsistent with modern engineering standards for proper road construction. Also present on the 2012 photo is a large debris landslide located upstream of the stream crossing that is likely compromising and/or plugging the culvert inlet with deposited sediment. It was likely triggered by initial road construction and/or ponding behind the culvert inlet caused by culvert plugging and subsequent saturation of the basal fill and hill slope.

As with the other stream crossing examples, long lengths of both adjacent road approaches and large cut bank bare soil areas drain runoff and sheet, rill and gully erosional products to the low point in the photo, the axis of the stream crossing (Figure 5 shows the approximate contributing drainage area). This runoff is also contributing to the developing instabilities observed on the fill slopes.

By the date of the December 2013 vertical satellite image, shown as well in the inset pair of photographs by Mende and Astorga (2013), uncontrolled runoff on the fill slopes has resulted in significant enlargement of the immense gully network, where virtually all the eroded sediment has been delivered down slope to the Rio San Juan.

As shown in the May 2014 oblique photo, no efforts have been made to control or prevent future erosion on the fill slopes, or to disconnect the adjacent road approaches from draining runoff and associated eroded sediment originating from the large expanses of bare soil visible in the photographs, directly to the stream crossing fill and ultimately to the Rio San Juan (Figure 4).

By May 2014, approximately half the road prism width, and a large portion of the outer fill slope, had already failed and delivered sediment downslope and downstream to the Rio San Juan (Figure 4). Substantial fresh deltas associated with the ongoing and uncontrolled erosion along Route 1856 are present in the Rio San Juan, and these will continue to enlarge during future storm events in the absence of redesign, reconstruction, and erosion control measures at the site, and/or road decommissioning. Over the 20 month period, no visible efforts at performing preventative surface, rill and gully erosion control measures, or slope stabilization measures, are visible on any of the failing fill slopes, or on the adjacent bare soil areas exposed along the road and cut bank approaches draining to the stream crossing. The very large stream crossing fill is in a complete state of disrepair and threatens to completely fail and deliver substantially greater volumes of eroded sediment directly to the Rio San Juan.

Using scaled measurements of gully features A, B and C on the December 2013 vertical satellite image (Figure 4), and assuming a conservative average gully depth of 3 meters (see person for scale on inset photo by Mende and Astorga in 2013, and bearing in mind that the photo was taken approximately one year prior to the visible site conditions present in the May 2014 oblique photo on Figure 4), we estimate the three gullies alone have eroded a minimum of 6,600 m^3 since road construction was initiated, and virtually all the eroded sediment has been delivered to the Rio San Juan.

As shown on Figure 5, we estimate the contributing drainage area to calculate additional surface, rill, gully and landslide erosion volumes at Site 9.6 as approximately 4,845 m^2. Using the average of the average rates for cut slope and fill slope erosion reported by Mende and Astorga (2013, Annex 6, Table 7) for landslide, gully and rill erosion (i.e. average rill = 0.205 m + average gully = 0.48m + average landslide = 0.99)/3 = 0.558 m/y), and assuming a combination of rill, gully and landslide erosion is occurring on 40% of the defined contributing area, approximately 1,081 m^3/yr of additional rill, gully and landslide erosion is occurring at Site 9.6 (Figures 4 and 5). Applying the average of Mende and Astorga's (2013, Annex 6, Table 7) estimated surface erosion rate of 0.095 m for cut slopes and 0.24 m for fill slopes = 0.168 m/y to the remaining 60% of the bare soil contributing area visible at Site 9.6 (Figures 4 and 5), an additional approximately 488 m^3/yr of material is being produced within the contributing drainage area by surface erosion processes annually at Site 9.6.

Our estimate of the total erosion of 8,169 m^3/yr and sediment delivery to the Rio San Juan at Site 9.6 is again substantially higher than the Mende and Astorga (2013) "worst-case" annual yield for this slope that was estimated at an unrealistically low 662 m^3/yr (Figure 4), including the combined volume of erosion from sheet, rill, gully and landslide erosion. Much more erosion and downstream sediment delivery has occurred since their field visit to the crossing, and yet nothing meaningful has been done to repair or alleviate the damage caused by the collapsing stream crossing fill, or the extensive surface, rill and gully erosion occurring on the bare soil areas. To put the scale of this erosion into perspective, the 8,169 m^3/yr of erosion from this site alone is equivalent to over 22% of the total annual sediment production Costa Rica asserts has been delivered from the entire 108-km of road along the Rio San Juan (Mende and Astorga, 2013, Annex 6, p. 402).

Recommended Solution

As described above, consistent with recommendations of the EDA (Annex 10 of the Costa Rican Counter-Memorial), we recommend this and the other two stream crossings at Las Crucitas be removed completely, as the road should be relocated farther inland to more stable terrain. The same requirements described above for Severely Eroding Sites 9.4 and 9.5 apply to this site: removal of all stream crossing fill material shown by the black trapezoid on the October 2012 photo (Figure 4), transport all the excavated material to a stable disposal site(s), restoration of the original bed of the stream, stabilization of side slopes along the stream channel, and stabilization of the extensive cut slopes through vegetation and geotechnical means, likely including horizontal drain pipes to reduce pore pressures and geo-grids and geotextiles to stabilize the exposed slopes. In some cases, over-steepened cut slopes may need to be laid-back further or terraced differently, a process that will generate additional spoil material to be removed and safely disposed of.

The volume of this crossing fill is the largest of all three crossings at Las Crucitas, approximately 44,000 m^3, the equivalent of approximately 5,500 dump truck loads. All of this fill material, as outlined on Figure 4 on the 2012 oblique photograph, must be removed from the site and transported to stable disposal site(s).

In addition, any potentially unstable road fills in between the stream crossing fills would also need to be removed and hauled to a stable disposal site. From our analysis of the imagery, it appears that the stream crossing fills constitute the bulk of the fill volume at Las Crucitas, but there will be some additional fill not accounted for in our volumetric analysis, and which will need to be disposed of as well.

Figure 7 (below) serves as an example to illustrate the road decommissioning procedure. On the 2014 satellite photograph we have plotted the location of the 5 Severely Eroding Sites and identified other road reaches that might display unstable cut- and fill-slopes in need of stabilization in relation to a potential long term, spoil disposal location. From the western edge of Severe Erosion Site 8.1 (at river mile 16.1 km), it is approximately 4.4 km for dump trucks to haul excavated material to the potential spoil location at river mile 20.5 km (i.e. the gentle topography behind the home site and east of the access road). If three teams of heavy equipment were utilized to decommission this reach of Route 1856, one team could be working Sites 8.1 and 8.2, another could be stabilizing cut- and fill-slopes at the identified intervening road segments while still providing a portion of the cut part of the road prism for dump trucks hauling spoil from Sites 8.1 and 8.2, and the third team could begin to vertically lower the upper one third of the large stream crossing fills at Sites

9.4, 9.5 and 9.6 while still maintaining dump truck passage for the other teams (Figure 7). All spoil material in this particular example to hauled west to east to the designated stable, spoil disposal location.

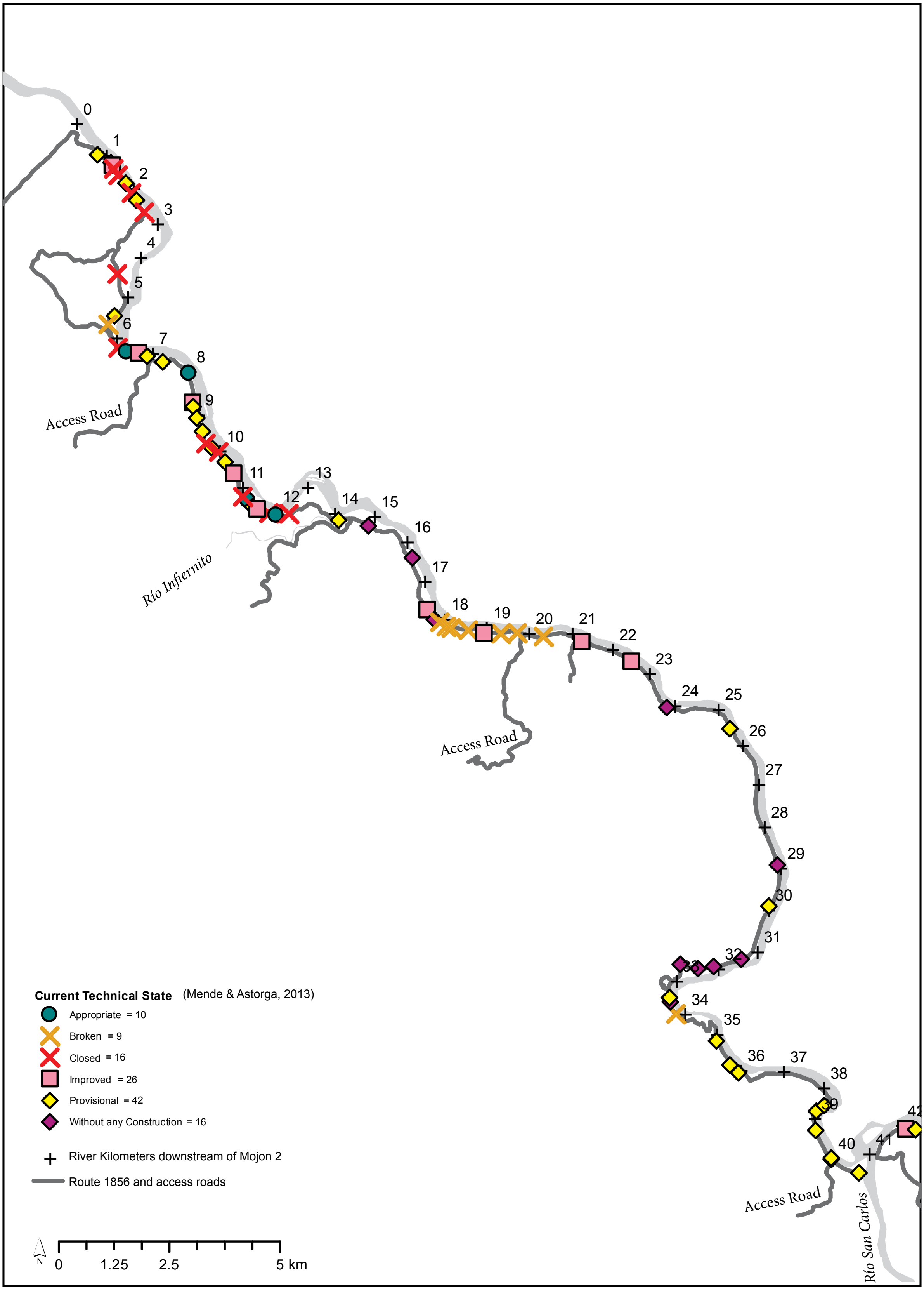
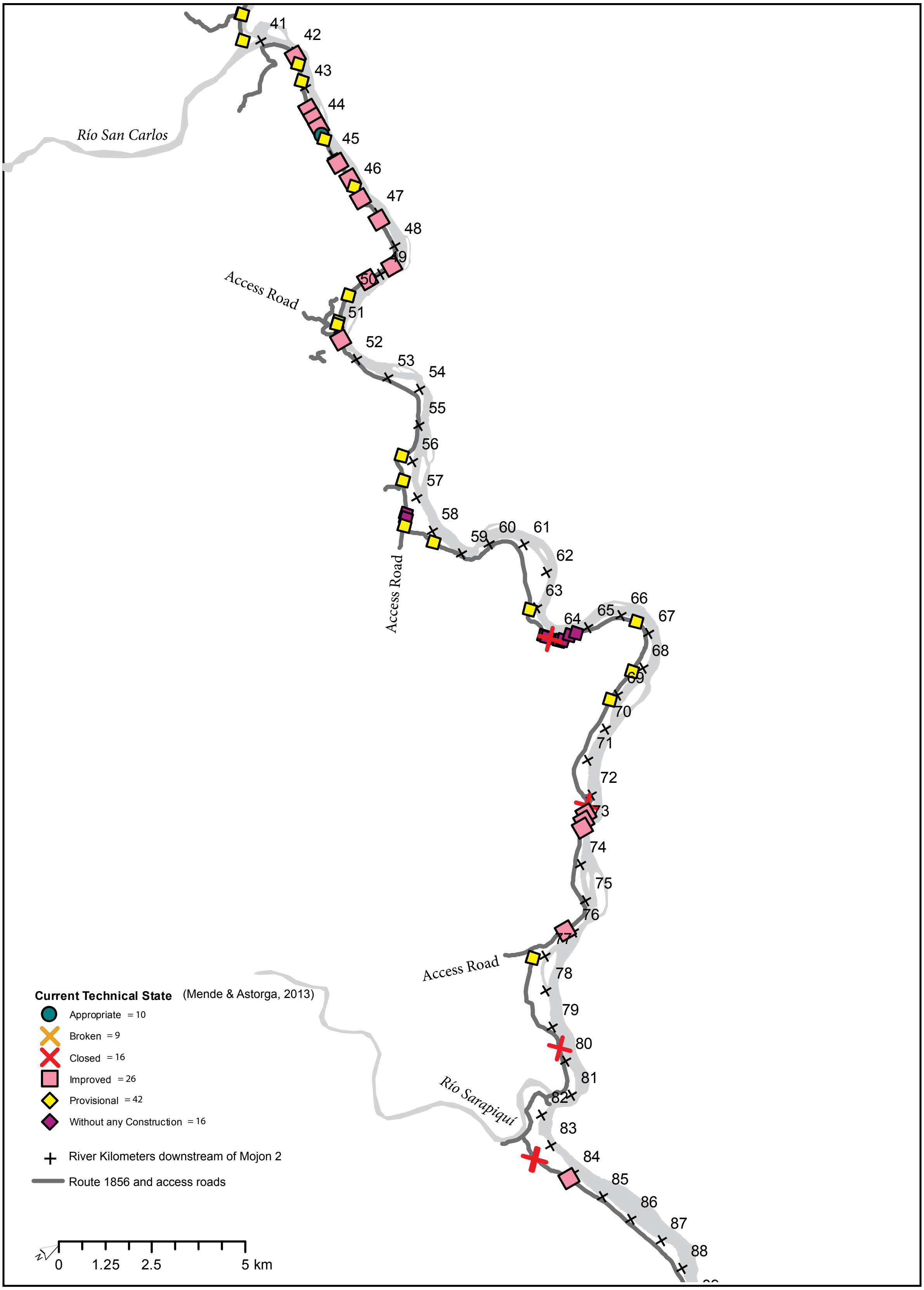


Figure 6. Map of road crossings derived from Mende & Astorga 2013, Annex 6 inventory of water crossings GIS database requested by Nicaragua in 2014. The map of technical states was not provided in Annex 6.



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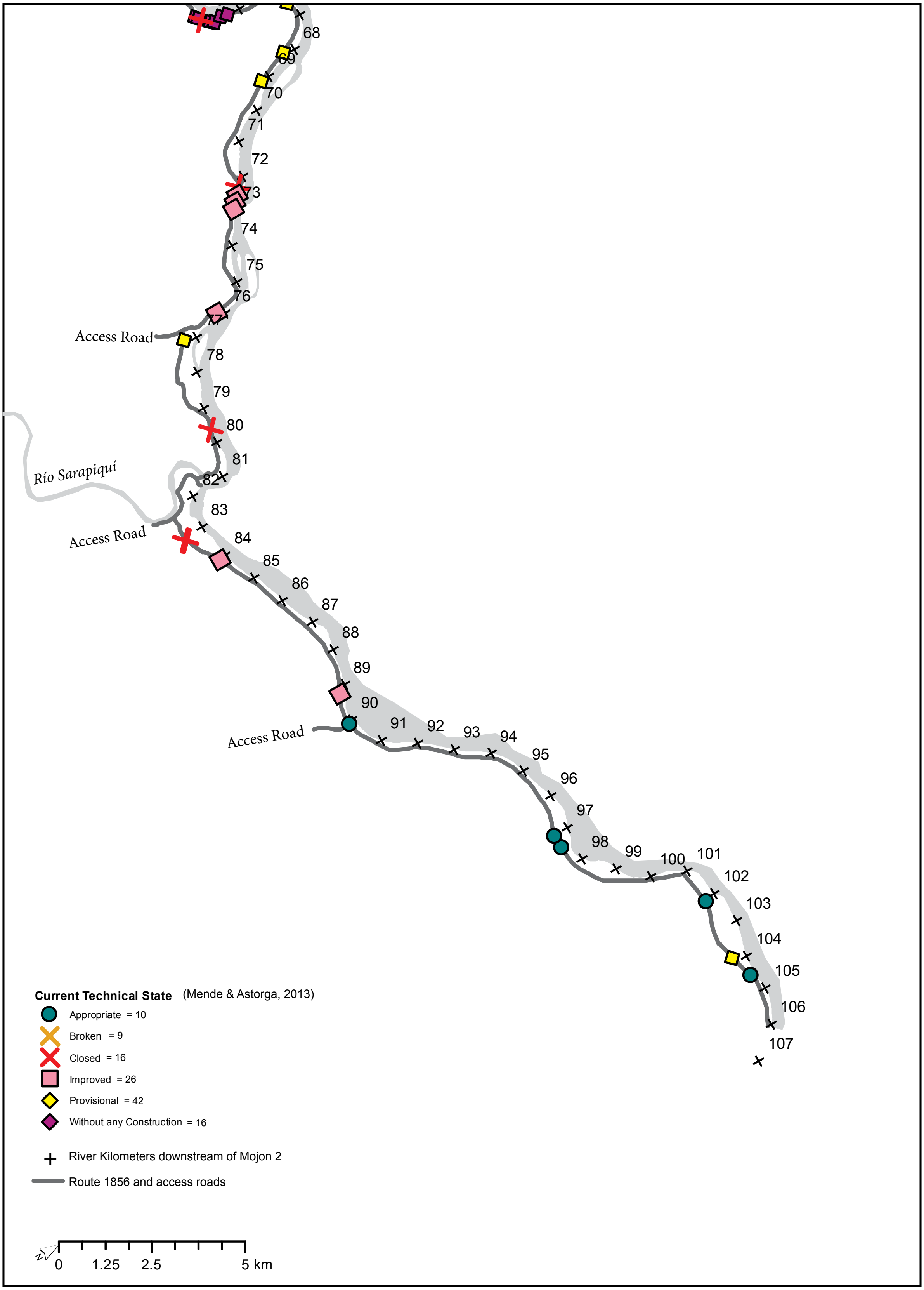


Figure 6. Map of road crossings derived from Mende & Astorga 2013, Annex 6 inventory of water crossings GIS database requested by Nicaragua in 2014. The map of technical states was not provided in Annex 6.

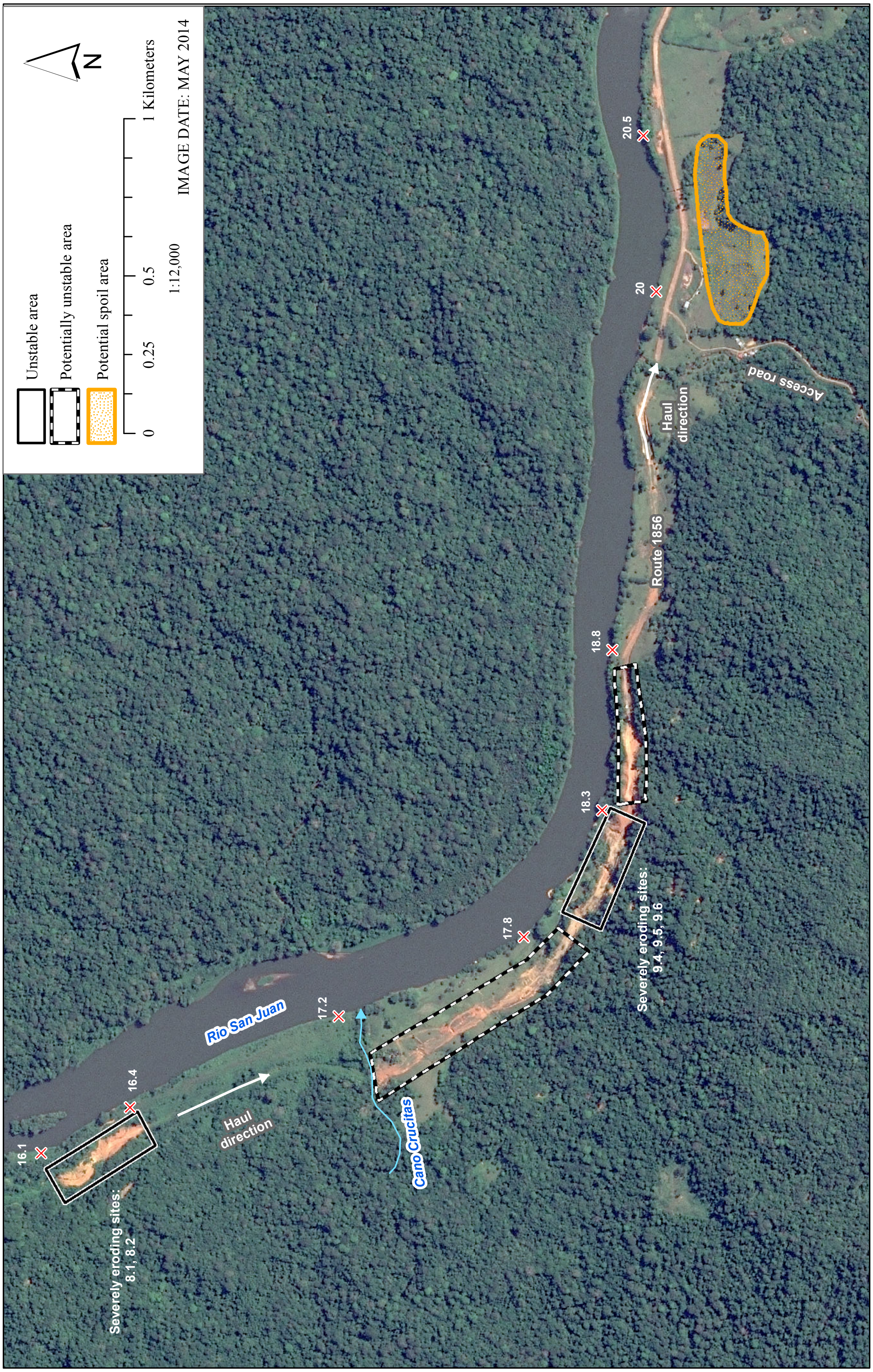


Figure 7. Example of road decommissioning procedures

E. *Summary of Stream Crossing Observations*

In summary, the Costa Rican repairs and erosion control efforts, as observed on the May 2014 photographs over a 20 month period, on three sets of example stream crossing sites are totally inadequate and ineffective at treating continuing road failures and ongoing erosion, and in preventing future erosion, at each site. If fact, the minimal nature of the spot technical improvements or road repairs that are visible appear to have been implemented solely to provide a narrow and unsafe vehicle route across each failing stream crossing; not to reduce erosion, protect the Rio San Juan or stabilize the site against further damage. The existing design and construction deficiencies described above, and the ongoing significant slope stability, gully and surface erosion problems at and adjacent to each of these sample sites indicate that portions of Route 1856, in its current condition, are extremely unsafe and will continue to severely impact the Nicaragua's Rio San Juan and its resources far into the future.

Even with our restricted ability to make direct physical measurements of erosional voids along the road, it is clear the Costa Rican reports have minimized and under reported the extent of erosion and downstream sediment delivery associated with the road, and consequently are under-estimating the ongoing cumulative sedimentological and biological impacts to the Rio San Juan. We have estimated significantly larger volumes of gully/landslide erosion at the three sample stream crossing sites than those published by Mende and Astorga (2013). Some of their low erosion rate estimates may be due to the fact that they measured a limited subset of erosion features along a less than representative range of features during a short time period in 2013, and the sites have continued to deteriorate and fail at an increasingly rapid rate. It is obvious based on the visual condition of the road on Figures 2, 3 and 4, that through this 20 month period, Costa Rica has done nothing of significance to curtail erosion and stream crossing failure at these three example stream crossing sites. When one Site (9.5) largely failed and washed out, delivering all its eroded sediment to the Rio San Juan, Costa Rica simply refilled the crossing with bulldozed fill and reset the potential failure mechanism by again using poor design and construction techniques. Even observed at a distance, their efforts and workmanship along these sample road sections has been completely unprofessional and inadequate, and their efforts (or lack of effort) have been done with complete disregard to the environmentally consequences to the Rio San Juan.

In addition, there is no doubt that all bare soil areas visible in these examples are eroding during every rainfall event by a combination of sheet wash (surface), rill and small gully erosional processes. It is clear and ubiquitously visible, even on aerial photographs. Where road bed segments and exposed cut bank areas along Route 1856 drain to the nearby 119 stream crossing documented by Mende and Astorga (2013) in Figure 6, or to gullies exiting the road, these bare segments of road and cut bank are likely to be hydrologically connected to the adjacent stream crossings and delivering erosional products to the receiving streams, and to the Rio San Juan. This mechanism of road bed sediment production and sediment delivery to Nicaraguan waters has not been acknowledged or measured by Costa Rican researchers.

Finally, Mende and Astorga's statement (2013, page 28) that "technical improvements have been made…and the crossings will continue to be in an acceptable condition in the medium-term," is contradicted by observable site conditions. The three photo examples we have presented (above) illustrate that little to no effective technical improvements or repairs have been made, and we do not consider these severely eroding stream crossings to be "in an acceptable condition". Nor do we agree with Mende and Astorga's statement that the road construction and repair efforts for Route 1856 "can be described as typical during a construction period" (Mende and Astorga, 2013, page 28). In our experience, Costa Rica's poor (or absent) design and construction standards, and the apparent lack of construction engineering oversight during road building, are completely contrary to modern road construction standards found in any design manual in the last 30 years. The result is far from typical.

The magnitude of ongoing and active erosion present along segments of Route 1856 confirms that the road was built with a total absence of plans, design and construction standards, and adequate stream crossing and road drainage structures (CFIA, 2012, pages 25 and 26, PITRA-LannameUCR, 2012, pages 48-51). Reconstruction and stabilization measures need to be undertaken immediately. Well-designed repairs, road decommissioning (removal) and/or complete reconstruction must be initiated and completed on an urgent basis if continuing and future damage to the Rio San Juan and Nicaragua's resources are to be minimized or reduced. Costa Rica's almost complete lack of action on this matter for the last 20 months is unacceptable from an engineering and environmental perspective, and their continued lack of action threatens even greater damage to the road, to the Rio San Juan and to the environment in the near future.

III. Severe Erosion at Fill Slopes and Cut Banks Documented by Time-Sequential Aerial Imagery

There are many locations along Route 1856 where recently constructed cut slopes and fill slopes are experiencing uncontrolled and inordinately high rates of erosion following construction. These large bare soil areas are eroding and failing by all three erosional processes: landsliding, gullying and surface erosion. While some efforts have been undertaken to stabilize a few of the locations, at many it appears as if the road has been abandoned and no efforts have been made to control or curtail the ongoing erosion and slope failures, or to reduce potential impacts to the Rio San Juan, over the 20-month period of our photographic record.

A. Severe Fill Slope and Cut Slope Examples at Two Sample Sites along Route 1856

Figures 8 and 9 illustrate two (2) examples of poorly designed, poorly constructed and unmaintained cut and fill slopes along Route 1856. Both image comparisons depict badly deteriorated and rapidly eroding and failing cut slopes and fill slopes located directly adjacent to the Rio San Juan. Aerial oblique photographs were taken comparing the sites over the 20 month time period between October 2012 and May 2014. Each of the two sites (Severely-Eroding Sites 8.1 and 8.2, in Appendix A of Kondolf 2014), located between 16-16.5 km downstream of Mojon II, exhibit extensive fill slope landslide instabilities that are enlarging through time; active and large scale gullying associated with poor road drainage practices and highly erodible, un-compacted materials; sporadic cut slope failures associated with undercutting and constructing over-steepened slope cuts in fine grained soils during the attempts at road construction; and widespread surface erosion from the extensive and easily visible bare soil areas present in the photographs.

Contrary to claims in Costa Rican documents that road repairs and maintenance are on-going, in both of the examples, there appears to have been no efforts over the 20-month time frame (Oct 2012 – May 2014) to implement any significant preventative erosion control measures to prevent or control ongoing erosion and slope failure. Given the observable high level of progressive instability seen in the photographs, and the evident lack of following even the most basic road engineering and construction principles, it is clear to us that few, if any, of the stream crossing fills and road fill slopes were properly compacted. Workmanship on critically important road segments on steep hill slopes right next to the Rio San Juan, like the ones in these examples, is unreasonably poor and unprofessional. They were either poorly designed or poorly constructed, or both. Regardless, the impacts to the Rio San Juan have been significant and threaten to be even larger with the passage of time.

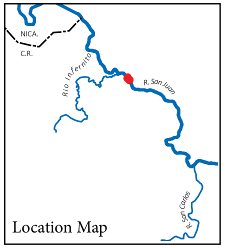
Figure 8. Severely Eroding Site 8.1
Pioneered but incomplete cut bank and sidecast fill slope located 16.1 km downstream from Mojon 2.

One of two large adjacent pioneered and abandoned road cuts with no attempts to mitigate erosion, as evidenced by conditions in May 2014 photographs. Gullying and landslides on the cut and fill slopes have increased. Lack of revegetation suggest continued soil instability and erosion.

The 2012 imagery cleary shows an arcuate head scarp with a length of 70m and a surface area of 1,300 m² measured in GIS. With a conservative estimate of 2m landslide depth, that equates to 2,600 m³ of sediment eroded before the 2012 imagery.

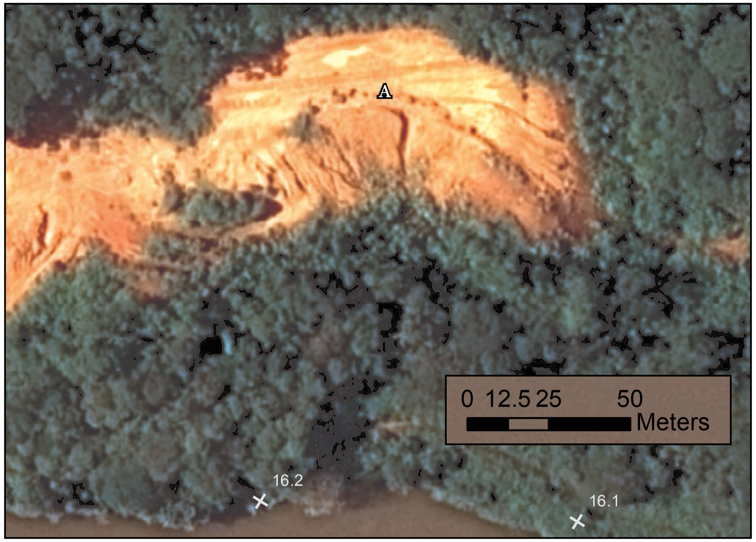
Gully A, one of several gullies on the fill slope, has a surface area of 110 m² and an average depth of 3m, indicating erosion of approximately 330 m³ of fill material since October 2012.

Mende & Astorga (2013) "worst-case" annual yield for this fill prism (T-064a,b) = 1006 m³/yr, which includes all sheet, rill, gully, and landslide erosion for the fill prism.



Deep gully on sidecast fill slope (from Mende & Astorga 2013, p40). View down the gully to Rio San Juan.

October 2012 photo from helicopter



December 2013 satellite image

May 2014 photo from helicopter

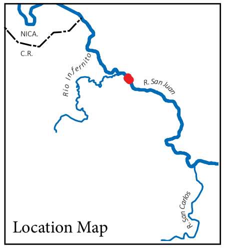
Location: 16.1 to 16.2 km downstream of Mojon 2 border marker.

Figure 9. Severely Eroding Site 8.2

Road fill crossing located 16.3 km downstream from Mojon 2.

One of two large adjacent pioneered and abandoned road cuts with no attempts to mitigate erosion, as evidenced by conditions in May 2014 photographs. Scarps A & B indicate failure of fill slope and road surface. Scarp A measures 50m in length with a surace area of 1079 m^2 while scarp B is 50m in length with a surface area of 1049 m^2. With a conservative estimate of 1.75m landslide depth, the failed volume of these 2 slides is 3,724 m^3 since road construction. Gullying and landslides on the cut and fill slopes have increased. Lack of revegetation suggest continued soil instability and erosion.

Mende & Astorga (2013) "worst-case" annual yield for this fill prism (T-065a,b) = 1238 m^3/yr, which includes all sheet, rill, gully, and landslide erosion for the fill prism.



Sediment delta of eroded roadfill material (May 2013).

Steep and unstables cut and fill slopes (from Mende & Astorga 2013, p40).

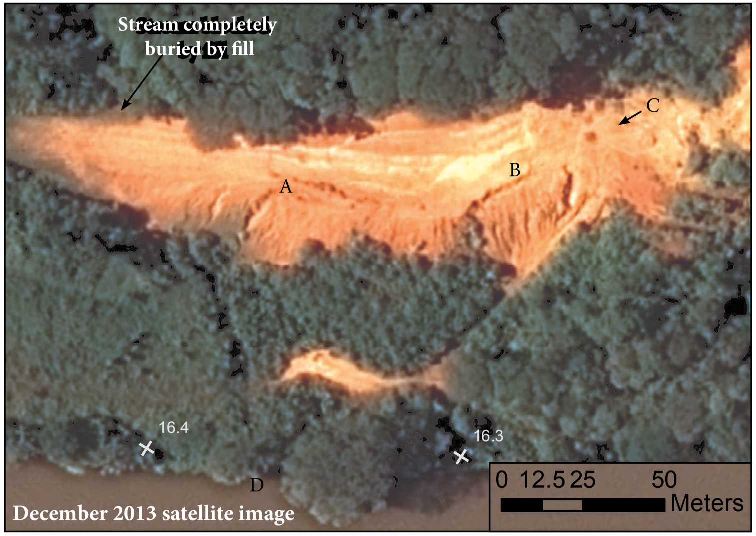
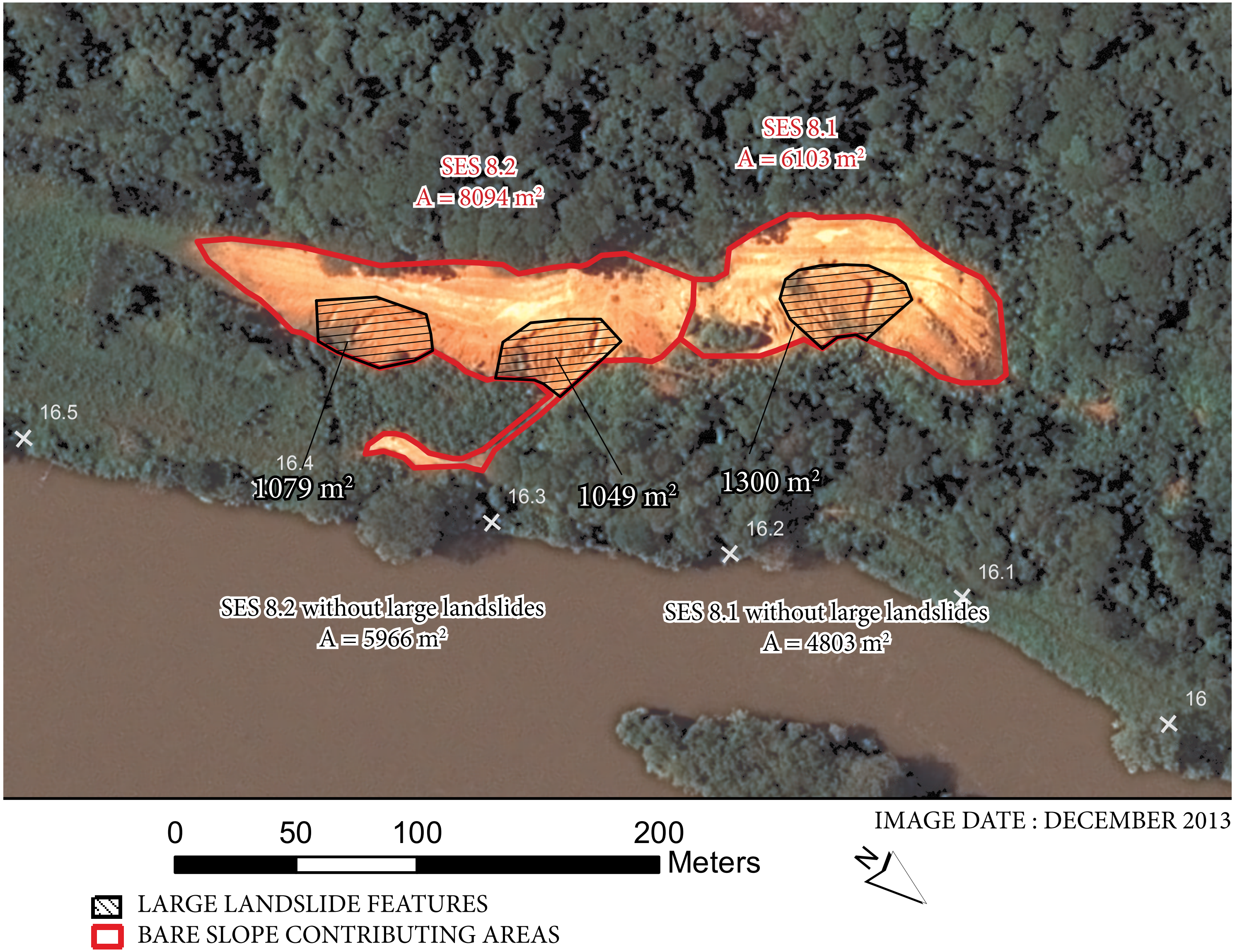


Figure 10. Delineation of bare slope contributing areas that are actively eroding at sites 8.1 and 8.2.



B. Severe Cut Slope and Fill Slope Site 8.1 at RSJ River 16.1 km

Severely Eroding Site 8.1, shown in Figure 8, is located 16.1 km downstream from Mojon II and shows a partially constructed (pioneered) reach of Route 1856 across a steep ridge between two adjacent tributary stream channels (not shown in the figure). This partially constructed road reach is located on steep hill slopes within 100 m of the Rio San Juan. The sequence of three images captured in 2012, 2013 and 2014 indicate initial construction activities were completed along the road reach by October 2012, and no visible or substantive work on the failing road has been done since 2012. This conclusion is based on the fact that the only visible changes during the 20 month time period are actively developing, uncontrolled and enlarging gullies and landslides present on the un-compacted, sidecast fill slopes, and evidence of widespread surface erosion on the visible bare soil areas through time. Poor or non-existent fill compaction during construction could have easily led an experienced geologist or engineer in October 2012 to predict the resulting instabilities and extent of erosion now present on the fill slopes at this site.

The images of Site 8.1 clearly indicate the reach of road was just abandoned (walked away from) following the 2012 construction work, with no visible efforts to address and control surface erosion from the large expanse of exposed bare soil through seeding and/or mulching the surfaces to protect the soil from raindrop impact and sheet wash erosional processes. In addition, the presence of the widespread and obvious gullies of varying dimensions visible on the 2013 and 2014 images clearly indicate that no subsequent efforts have been made to manage and/or disperse concentrated runoff from the many hectares of exposed road, cut bank and fill slope bare soil areas. The developing gullies are undermining and further contributing to the formation/incidence of fill slope failures observed and present on the 2014 photograph.

Each of these deficiencies in road design, construction, erosion control and pre-wet season stabilization procedures conflict sharply with well-established road design and construction standards, and these deficiencies during major road construction and lack of repair or maintenance efforts at the scales observed along portions of Route 1856 have not been observed in the U.S. for three or four decades. In the absence of implementing immediate erosion control and slope stabilization measures at this and other similar cut bank, road prism and fill slope areas along Route 1856, future storms larger than those experienced to date will almost assuredly lead to additional and more significant fill failures and sediment production (and delivery to the Rio San Juan) than currently is visible on the imagery.

Evidence for extensive ground surface lowering due to surface erosional processes is obvious on the cut bank areas (Figure 8). One can see where the difference from a smooth textured excavation surface in the 2012 photo, has evolved into a very coarse, rough textured erosion surface in the 2014 photo. The eroded surface appears to have exposed the layered stratigraphy of the underlying bedrock (rock layering), as a result of 20 months of rainfall and associated uncontrolled sheet wash and rill/gully erosion of the bare soil areas.

The prominent crown scarp outlined on the October 2012 oblique photograph indicates that deformation of the recently sidecast and un-compacted fill was occurring within 1 year of the start of construction along Route 1856. Utilizing GIS measurements on the satellite imagery, the crown scarp is estimated to be approximately 70 m long with an unstable fill slope surface area of 1,300 m^2 (Figure 8). Applying a conservative estimate of 2 m average depth for the landslide, we estimate that a volume of 2,600 m^3 failed and moved downslope. In addition to the large unstable fill slope area, uncontrolled and concentrated runoff from the large expanse of bare soil area visible in the photos has resulted in the formation of several gullies on the fill slope, with the largest being identified as location "A" (Figure 8). The surface area of the gully at location A is estimated to be 110 m^2, and applying an average estimated depth of 3 m yields an additional eroded volume of 330 m^3 from this one feature.

Excluding the 1,300 m^2 area of gully A and the large unstable fill slope area described above (which is conservative, as additional erosion is clearly taking place on the fillslope, where the landslide occurred prior to October 2012), we estimate that the remaining contributing drainage area of exposed bare soil (i.e. where erosional products will move or be transported downslope toward the Rio San Juan and into the undisturbed forest) is 4,803 m^2 (Figure 10). Using the average of the average rates for cut slope and fill slope erosion reported by Mende and Astorga (2013, Annex 6, Table 7) for landslide, gully and rill erosion (i.e. average rill = 0.205 m + average gully = 0.48m + average landslide = 0.99)/3 = 0.558 m/y), and assuming that a combination of rill, gully and landslide erosion is occurring on 40% of the defined area on Figure 10, approximately 1,072 m^3/yr of additional rill, gully and landslide erosion is occurring at Site 8.1 (Figures 8 and 10). Applying the average of Mende and Astorga's (2013, Annex 6, Table 7) estimated surface erosion rate of 0.095 m for cut slopes and 0.24 m for fill slopes = 0.168 m/y to the remaining 60% of the bare soil contributing area visible at Site 8.1 (Figures 8 and 10), approximately 484 m^3/yr of material is being produced within the defined bare soil drainage area by surface erosion processes annually at Site 8.1.

Combined, we estimate the bare soil areas at Site 8.1 produced at a minimum approximately 4,156 m^3 of sediment in the first year after construction, via a combination of sheet, rill, large and small gully and landslide erosion processes, (i.e. from within the contributing area shown on Figures 8 and 10), and a minimum of approximately 1,886 m^3 in the 20 months between October 2012 and May 2014.

Recommended Solution

As noted above, this section of road should be decommissioned (i.e. removed and stabilized) and a new route be properly designed in a less-steep, inland location. While moving the road will provide a better situation for future road stability and erosion management, there is the problem of how to manage erosion along the steep slopes above the river at this site. For the loose, eroding fills, the following steps are required:

A. As soon as weather and soil conditions permit, mobilize heavy earthmoving equipment to excavate the entire mass of fill that originated from the cut slope and was sidecast down the hillside.

B. Identify a stable spoil disposal location(s) on flat ground that is more than 100 m in distant from the Rio San Juan or its tributaries, and upon which vegetation can be established to stabilize the spoil material, such that the spoils will not be eroded and transported to the river.

C. As discussed earlier, it appears that the best access to the eroding cut and fill slopes at Severe Erosion Site 8.1 and 8.2 for dump trucks would be from the southeast, so that the clean-up of these sites would need to be coordinated with the cleanup of the three stream crossings at Las Crucitas, so that trucks could end haul excavated materials to the suggested potential spoil disposal site shown on Figure 7 at approximately river mile 20.5 km.

D. The danger of having heavy trucks using the unstable crossings at Sites 9.4, 9.5 and 9.6 must be taken into account, and the stability of these crossings (after their temporary repairs) should be monitored closely when in use to transport spoils, such that their use is discontinued at the first indications of deformation and instability due to the heavy loads of dump trucks end-hauling spoils.

E. End haul with dump trucks the excavated spoil materials to the disposal site.

F. Stabilize exposed cut slopes by reseeding and planting (where possible given slope conditions), and where indicated by qualified experts, implement other techniques to improve slope stability, such as horizontal drains, geotextile and geo-grids.

G. If cut slopes are determined to be significantly over-steepened, it may be necessary to lay them back to a more stable angle to reduce the likelihood of cut slope failure. Unfortunately, this would require further cutting of the slope and would generate additional spoil material to be removed and safely disposed of. Because of the further disturbance and additional spoil created by laying back the cut slopes, this technique should be implemented only where indicated by qualified experts who have the opportunity to visit the site and conduct the necessary tests of material strength, perform long term slope stability evaluations, and who determine that the benefits of the action would outweigh its impacts.

C. Severe Cut and Fill Slope Site 8.2 at RSJ River 16.3 km

Shown in Figure 9 is Severely Eroding Site 8.2, which is located 16.3 km downstream from Mojon 2. This is another pioneered and incompletely constructed reach of Route 1856 that crosses a steep ridge area between two adjacent tributary stream channels, one of which has been completely buried by recently bulldozed road fill with no obvious drainage structure (see lower left side of the 2013 satellite image). Similar to Site 8.1, the road construction area has been abandoned since October 2012, and illustrates no efforts to perform post-construction site or slope stabilization or to implement pre-wet season temporary, permanent, or emergency erosion control measures.

The total absence of road design and construction plans or standards, and the lack of competent construction inspection and management at this site and others along Route 1856, has resulted in the immediate and progressive development of cut slope and fill slope instabilities over the 20 month period covered by these images of the site.. The substantial erosion and slope instability has developed in less than two relatively dry years. On the October 2012 oblique photo (Figure 9) can be seen the cut slope landslide that developed almost immediately in the center of the photo. Also evident is the developing arcuate crown scarp system along the outer edge of the road, indicating pending fill slope failures within the un-compacted, loose sidecast fill materials that had been bulldozed onto the steep hill slope during road building. In the December 2013 vertical satellite image and the May 2014 oblique aerial photograph, the scarp system continues to be more pronounced and integrated along the outside edge of the road, as the unstable fill slopes continue to deform.

Additionally, two more recent and larger cut slope failures are visible at either end of the cut bank in the May 2014 photo. These features clearly suggest there was little or no pre-construction geotechnical analysis of the terrain and subsurface geology that would have indicated the unstable nature of the earth materials. This common-place and standard geotechnical and geologic analysis would have predicted the lack of soil and bedrock competency and strength, and subsequently would have been used to develop proper engineering designs for this and other sites along the road which are now exhibiting massive surface erosion and road failure.

As is visible in the images at Site 8.2, and elsewhere along Route 1856 where the road crosses steep hill slopes, the construction also lacks any visible efforts at designing road surface and cut slope drainage design and structures that would have been suitable to manage and control surface runoff. These design and construction deficiencies, as well as poor practices and poor workmanship, are resulting in the development and enlargement of an extensive network of various sized gullies that are visibly expanding on the over-steepened and un-compacted fill slopes. As shown on the 2013 and 2014 images, the two largest gullies at Site 8.2 are coincidently located along the lateral scarp margins that define the most unstable and actively failing fill slopes at the site.

The pair of prominent crown scarp outlined on the October 2012 oblique photograph again indicate that deformation of the recently sidecast and un-compacted fill was occurring within 1 year of the start of construction along Route 1856 (Figure 9, Locations A and B). Utilizing GIS measurements on the satellite imagery, both outlined crown scarps are estimated to be approximately 50 m long with an unstable fill slope surface area of 1,079 and 1,049 m^2, respectively (Figure 9). Applying a conservative estimate of 1.75 m average depth for the two largest failing fill slopes and erosional features visible in the photos (Figure 9, see inset photo C by Mende and Astorga, 2013), we estimate that a volume of at least 3,724 m^3 has moved downslope in these two locations since construction, equivalent to over 1,241 m^3/yr when averaged over three years.

Excluding the 2,128 m^2 area delineated on Figure 10 that was used to estimate the volume of the fill slope landslide visible at Site 8.2, we estimate that the remaining contributing area of exposed bare soil (i.e. where erosional products will move or be transported downslope from Route 1856 into the undisturbed forest and toward the Rio San Juan) is 5,966 m^2 (Figure 10). This is conservative, as erosion is still taking place on the old landslide scar as well. Using the average of the average rates for cut slope and fill slope erosion reported by Mende and Astorga (2013, Annex 6, Table 7) for landslide, gully and rill erosion (i.e. average rill = 0.205 m + average gully = 0.48m + average landslide = 0.99)/3 = 0.558 m/y), and assuming that a combination of rill, gully and landslide erosion is occurring on 40% of the defined area on Figure 10, approximately 1,332 m^3/yr of additional rill, gully and landslide erosion is occurring at Site 8.2 (Figures 9 and 10). Applying the average of Mende and Astorga's (2013, Annex 6, Table 7) estimated surface erosion rate of 0.095 m for cut slopes and 0.24 m for fill slopes = 0.168 m/y to the remaining 60% of the bare soil contributing area visible at Site 8.2 (Figures 9 and 10), approximately 601 m^3/yr of material is being produced within the defined bare soil contributing area by surface erosion processes annually at Site 8.2.

Combined, we estimate that the bare soil areas at Site 8.2 produced a minimum of approximately 3,174 m^3/yr of sediment via a combination of sheet, rill, large and small gully and landslide erosion processes (i.e. from within the contributing area shown on Figures 9 and 10). This estimate of total erosion at Site 8.2 is significantly higher than Mende and Astorga's (2013) reported estimate of total sediment production from this site of 1,238 m^3/yr (including sheet, rill, gully and landslide erosion) (Figure 9), a significant under-representation of the actual erosion documented in the imagery.

Recommended Solution

As per Site 8.1, with the re-routing of the road to a more stable location to the south, the loose fill-slope material must be removed to a stable disposal site.

As per sites discussed above, after the fill material was removed, the exposed cut slope would need to be stabilized through vegetation, use of geo-grids and geotextiles, horizontal drains, and possible laying back of the slope to reduce the cut slope angle.

D. Summary of Cut Slope and Fill Slope Observations

Over the 20 month period of our analysis of oblique aerial photographs and high-resolution satellite images, there is a clear lack of any significant or visible efforts to control, repair or prevent the very visible, ongoing and future landslide, gully and surface erosion that is apparent in the two cut and fill slope examples. The incompletely constructed road reach at Site 8.1 and 8.2 reveals a complete disregard for following even the most basic, well accepted road engineering and road maintenance principles normally applied during road construction. Even more egregious is the total disregard for site specific and cumulative environmental impacts that continue to be experienced by Nicaragua, as well as to Costa Rican natural resources.

The above discussed fill and cut slope examples violate virtually every relevant road design, road layout, road construction, road maintenance, and temporary and emergency erosion control standard and measure.

IV. Recommended Erosion Control Solution along Route 1856 where the Road will Remain in its Current Location

There are many locations along the 108 km long Route 1856 between Mojon II and the confluence of the Rio Colorado where there is active, ongoing erosion or potential erosion occurring where it is unlikely that the road will be decommissioned and re-located farther inland in order to protect water quality. For example, Appendix A identifies 18 additional locations along the road, excluding the 5 Severe Erosion Sites discussed above, that exhibit some combination of uncontrolled surface, rill, gully and landslide erosion or erosion potential associated with poor road design, location, construction and post construction temporary and long term erosion control measures. The following recommendations should be followed in order to stabilize and prevent continued impacts to the Rio San Juan.

A. Recommended Stream Crossing Mitigation Approaches

According to Mende and Astorga, (2013, p. 399 of Annex 6) 83 of the 119 (70%) of the stream crossings along Route 1856 have been classified as to their technical status as being “broken, closed, provisional or without any connection” (Figure 6). Whether these stream crossing sites ultimately will require bridges or properly sized culvert drainage structures, each crossing must be constructed or re-constructed utilizing sound geologic, engineering and compaction standards. The process for constructing stable stream crossings that are resilient to future large storms and safe for commercial use requires following design, construction and maintenance principles that include, but not limited to:

A. As soon as weather and soil conditions permit, mobilize heavy earthmoving equipment to stabilize failing stream crossings by excavating all unstable or potentially unstable, poorly compacted and over-steepened fills at all road-stream crossings.

B. As soon as weather and soil conditions permit, mobilize heavy earthmoving equipment to stabilize failing or potentially unstable road fills on the immediate road approaches to stream crossings by excavating all unstable or potentially unstable, poorly compacted and over-steepened fills.

C. End haul with dump trucks the excavated spoil materials to stable spoil disposal locations where the soils will not be eroded and delivered to the Rio San Juan or its tributaries.

D. Poorly designed road-stream crossings fills should be immediately removed until they can be properly designed and constructed. These sites include those crossings where:

   i. road-stream crossing culverts and bridges have been constructed with unsuitable materials (e.g., logs, metal shipping containers, etc.), or

   ii. stream crossing structures have not been designed (engineered) to accommodate the 100-year return interval runoff event, or

   iii. road-stream crossing bridges or culverts have been misaligned with the natural channels or where drainage ditches have been excavated to re-route the stream flow out of the natural channel, or

   iv. the upstream and downstream fill slopes are over-steepened as reflected by ongoing deformation, gullying and landsliding.

   Removal of these poorly designed and/or constructed road-stream crossings should consist of:

   v. excavating and removing the drainage structure(s),

   vi. excavating all the fill materials out of the stream crossing so as to "exhume" the original channel bed, re-establish the natural thalweg channel gradient and flood flow width, and provide stable side slopes with either the natural side slope angle or a maximum 2:1 side slope, and

   vii. seed and mulch bare exposed soils for temporary erosion control.

E. The stream crossings can be properly reconstructed in the future once they have been properly designed using a) the proper materials, locations, orientations and sized drainage structures to accommodate the 100-year flow along with woody debris that will be in transport, b) sufficient drainage structure length to construct stable, compacted fill slopes and transport stream flow beyond the base of the fill slopes and construction site right-of-way, and c) construct stable, structurally reinforced and properly compacted engineered fill slopes designed to be resilient to large, prolonged infrequent storms.

B. Recommended Fill Slope Mitigation Approaches

It is necessary to reduce the rate and frequency of road fill failure slumps and landslides where the road crosses the steeper hill slopes, especially in all locations where failed or eroded soil materials could potentially be delivered to the Rio San Juan. This entails:

A. As soon as weather and soil conditions permit, mobilize heavy earthmoving equipment to excavate all unstable and potentially unstable sidecast fills. Hydraulic excavators will be required, and in many locations temporary benches and access spur roads will be required to reach all the unstable and failing fill materials (i.e. from near the base of the fill slope up to and through the outside edge of the road prism). Long boom excavators may be useful for reaching and removing unstable spoil materials where a temporary access road cannot be safely built.

B. Dump trucks may be required for end-hauling the excavated spoil materials, i.e. where necessary and when spoil cannot be stored in a dispersed manner along the cut slopes, for disposal at stable, low gradient locations where the materials will have no potential for re-mobilization and delivery to streams or wetlands.

C. It should be noted that seeding, mulching or planting unstable and failing fills, or employing various geotextile fabrics designed for surface erosion control, are not acceptable methods for controlling active or potential mass wasting processes.

D. Once the identified unstable fills have been excavated and removed, the road will largely consist of a full bench road bed with little or no part of the road constructed on fill material. If road widths are insufficient to accommodate the expected traffic in these treated reaches, either the cut portion of the road can be moved farther into the hill slope (provided the earth materials are stable) or a well designed and constructed engineered fill/retaining walls can be built along the outside of the road to ensure the new fill slopes remain stable during large infrequent return interval rainfall events. The structural fill should be designed by a qualified geotechnical engineer who should also be present during construction.

C. Recommended Surface Erosion Mitigation Approaches

It is necessary to immediately reduce road surface erosion and sediment delivery by improving dispersion of concentrated road runoff and increasing the number and frequency of road drainage structures. This measure will address gully erosion and hydrologically connected road segments that are currently delivering sediment to the Rio San Juan and its tributaries. This involves:

A. As weather and soil conditions permit, and after excavating all the fill slopes exhibiting instabilities referenced in Recommendation #1 (above) along Route 1856, immediately construct temporary rolling dips, cross road drains and/or waterbars at average 15 meter intervals (or more frequently) to drain road surface runoff to the outside edge of the road.

B. Construct surface drainage structures at close enough intervals so they will not result in new gully formation capable of transporting eroded sediment to the Rio San Juan or its tributaries. Some erosion of the road fill slopes can be expected, but sediment should be deposited on the native hill slope beyond the base of the fill and not transported to the river or a stream. Culvert down drains can be constructed to carry road surface runoff down the fill slope and to the base of the fill wherever the road is too close to the river to prevent sediment delivery.

C. Ensure that every drain or waterbar is constructed at a slightly steeper slope angle/gradient than the existing road gradient where the drain is constructed, so that they will be self-flushing and self-maintaining.
D. Ditches should be drained under the road using ditch relief culverts installed at sufficient intervals to prevent gullying of the fill slope or the natural hillside beyond the base of the fill where they discharge.

E. Ditch drains and road surface drains should be placed close on each approach to tributary stream crossings so as to divert surface runoff onto natural, undisturbed hill slopes, and thereby prevent or minimize road surface runoff delivery to streams that flow into the Rio San Juan.

F. Maintain all surface drainage structures and ditch drains so they continue to function as intended and so eroded sediment is not discharged to the Rio San Juan or its tributaries. If drainage structures are damaged by traffic or equipment, they should be rebuilt before the next rainfall and runoff event.

D. Recommended Surface Erosion Control Approaches for Bare Soil Areas

Finally, as noted above, in addition to methods to stabilize cut slopes (such as geo-grids, geotextiles, horizontal drains, and where indicated, laying back slopes to more stable angles), surface erosion should be controlled using the following methods:

A. Seed and mulch all bare soil areas with any potential for sediment delivery to nearby streams/wetlands with straw mulch at a rate of 4,000 lbs/acre (4,485 kg/ha) and native seed at a rate of 50 lbs/acre (56 kg/ha). If mulches other than wheat or rice straw are employed, ground coverage should be at least 95%.

B. Cut banks with slopes steeper than 50% will likely require the combined use of seeding, mulching and installation of rolled erosion control fabrics, stapled to the slope, to control surface erosion.

C. Inspect, re-treat and maintain all erosion control measures so they continue to function as intended and they prevent sediment delivery to the Rio San Juan and its tributaries.

DANNY K. HAGANS
PRINCIPAL EARTH SCIENTIST

SPECIALIZATION: *Applied geology and geomorphology, surface water hydrology, watershed assessment and restoration, erosion and sediment control, forest and rural roads, Quaternary stratigraphy*

QUALIFICATIONS:
Principal Earth Scientist, Pacific Watershed Associates Inc., 1990-present
Geologist, Redwood National Park, Arcata, CA, 1978-1990
Mining Geologist, Western Nuclear Corp., Jeffer City, WY, 1977-1978
Geologist, Six Rivers National Forest, Eureka, CA, 1974-1975

B.S., Geological Sciences, Humboldt State University, 1978

Certified Soil Erosion and Sediment Control Specialist #494

Advisory Board, Arcata Community Forest, Arcata, CA, 1986-present
Member: Watershed Management Council
Geological Society of America
American Geophysical Union
Salmonid Restoration Federation

SUMMARY OF EXPERIENCE:
Danny Hagans has extensive experience in conducting large scale, basin-wide erosion inventories and assessments, as well as implementing watershed rehabilitation and restoration projects in the western U.S.A. Mr. Hagans has 12 years professional experience as a lead U.S. National Park Service (Department of the Interior) geologist at Redwood National Park, California, developing and implementing the Park's internationally recognized, $50M watershed rehabilitation and restoration program. He specifically investigated the role of forest land use and road construction on erosion and sedimentation on the sediment budgets of coastal watersheds and is considered a leading expert in these fields.

The watershed rehabilitation program at Redwood National Park was the first of its kind, and of its scale, to be attempted in North America and perhaps worldwide. It was a program designed to protect and restore internationally valuable ecological resources within its boundaries (Redwood National Park is a U.N. World Heritage Site) from the impact of past forest management and road building. Mr. Hagans played a key role in organizing and implementing that program from its inception through its first decade. The groundbreaking watershed restoration program focused on the assessment of erosion problems and water pollution threats largely derived from 250 miles of major and secondary forest and ranch roads that had been constructed on what had recently become federally owned National Park lands. These eroding and failing roads had been constructed on industrial forest lands in the lower portion of the 280 mi^2 Redwood Creek Watershed, which was acquired by the U.S. federal government in 1978. At risk was Redwood Creek, a large coastal river with threatened and endangered fish species, the valuable ecosystem that supported those and other aquatic species, and world's tallest trees growing along its banks and on its floodplains.

Much of the extensive road network in Redwood Creek had been poorly planned and constructed on steep forest lands in a Mediterranean climate dominated by heavy winter precipitation, steep mountainous hillslopes and highly erodible, unstable terrain. Mr. Hagans was a key member of the team that identified problems and then designed, tested and implemented a wide variety of innovative road-related erosion control and erosion prevention techniques across the landscape. Redwood National Park's watershed restoration and sediment control program has served as the model for watershed erosion control and erosion prevention, and as a methodology for landscape-level water quality and river protection throughout North America.

While at Redwood National Park, Mr. Hagans was also responsible for conducting geomorphic research projects on erosion and sedimentation processes, especially focusing on the impacts of land management and road building. During his tenure with the federal government, Mr. Hagans conducted extensive and repeated technical reviews of proposed land use, and provided mitigations to private land owners and industrial forest managers on how they could conduct their timber harvesting, road building and land development projects upstream from Park lands without adversely impacting downstream areas.

Mr. Hagans joined Pacific Watershed Associates (PWA) in 1990, as principal and a co-owner of the company. Today, PWA is a full service geological and hydrological consulting firm, consisting of a staff of 30 full time geologists, geomorphologists, watershed scientists and physical science technicians, specializing in the development of science-based, technically sound management, restoration and geologic solutions for watershed, forest, estuarine, and riverine habitats. PWA is nationally recognized for groundbreaking work in watershed restoration, erosion control and aquatic habitat protection projects, and Mr. Hagans has developed state-of-the art protocols and state-adopted standards for watershed erosion assessments, watershed erosion prevention plans, road construction and road management practices and road decommissioning protocols.

Under Hr. Hagans guidance, the company specializes in developing and implementing plans for minimizing or mitigating the impacts of land management activities on geomorphic systems, including upland watershed areas, rivers, streams, and coastal areas. For example, over the 5 years from 2003 through 2008, PWA professionals completed 68 projects to document erosion problems along more than 3,800 miles of forest, ranch and rural road systems in watersheds where water quality and salmonid habitat are threatened by continued sedimentation. In this same time period, and with the assistance of both public and private partners, PWA conducted or supervised 82 projects to remediate erosion problems, including upgrading or decommissioning approximately 650 miles of roads in managed wildland watersheds, resulting in over $26,000,000 in direct funding for local contractors and workers.

Mr. Hagans has managed and conducted a wide array of projects related to wildland geomorphology, hydrology and erosion processes. Over his career with PWA he has personally conducted sediment source assessments of over 2000 mi^2 of managed forest and ranch lands in the Western U.S.A., and the preparation of sediment reduction plans for literally thousands of miles of wildland forest, ranch, and rural roads; vineyard roads; parkland roads; and county maintained public roads. He has conducted a number of sediment source investigations for federal and state agencies, industrial forest landowners and individual private landowners. Mr. Hagans has also completed dozens of studies and erosion prevention plans for northern California Indian Tribes, State Agencies, rural subdivisions, and industrial and non-industrial forest and ranch landowners. Mr. Hagans is a recognized and leading national expert in the identification and treatment of watershed erosion and sedimentation problems, especially those related to land management and road construction. The focus of these prioritized action plans, and their subsequent treatment, revolves around the protection and restoration of water quality, fisheries and aquatic habitat.

Mr. Hagans has conducted research and published articles on the magnitude and causes of forest land erosion, and especially on the effects of land use on erosion rates and processes, and cumulative watershed effects. His most recent (2014) publication is a comprehensive, 416 page manual on forest, ranch, and rural roads, published in both English and Spanish (*Handbook for Forest, Ranch and Rural Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Upgrading, Maintaining and Closing Wildland Roads*). He is also co-author of two U.S. Geological Survey Professional Papers, the original 1994 "*Handbook for Forest and Ranch Roads*" (commissioned by the California Department of Forestry and the U.S. Soil Conservation Service), Chapter 10 of the California's State-adopted Fish Habitat Restoration Manual ("Upslope assessment and restoration practices") and numerous other reports and papers. The California State Resources Agency calls PWA's 1994 publication, *Handbook for Forest and Ranch Roads*, the "definitive book on managing forest roads" that "belongs on every forest landowner's bookshelf." Mr. Hagans has also prepared and presented over 85 technical trainings for landowners, government agencies, and environmental organizations on erosion and sediment control for forest and rural roads through the Western U.S.A. In 2001, he was awarded the Nat Bingham Memorial Restorationist of the Year award by the Salmonid Restoration Federation. Mr. Hagans is currently serving as an appointed member of the Arcata Community Forest Advisory Committee for the city of Arcata, California.

In 2008, Pacific Watershed Associates received special recognition from the U.S. House of Representatives, the California State Senate, and the California Assembly for their work in watershed restoration and fisheries protection. PWA, and its founders Danny Hagans and Dr. William Weaver, was also recognized by *The Alliance for Sustainable Jobs and the Environment* as the 2008 Restoration Organization of the Year, representing the single organization to have "*achieved highest level of excellence and has had the most beneficial impacts on fisheries and watersheds in pursuit of the health and abundance*." The award cited their pioneering efforts to rehabilitate and restore the landscape of heavily damaged lands added to Redwood National Park, and to be "*at the forefront of a revolutionary approach to watershed restoration focusing on slope stabilization and recovery of* *hydrological integrity -- leading to prevention of stream sedimentation -- through methodical evaluation followed by careful and intensive corrective and/or constructive measures with heavy equipment*." ASJE recognized PWA and its founders, Dr. William E. Weaver and Danny K. Hagans, for "*…truly pioneering efforts. Their work, as well as that of a multitude of others who have adopted their techniques and systems, has kept millions of yards of soil material on slopes throughout Northern California and out of our precious rivers and streams. They continue to provide guideposts that are usable as well as an inspiration*."

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WILLIAM E. WEAVER

CEO, PRINCIPAL GEOMORPHOLOGIST

SPECIALIZATION: *Fluvial and hillslope geomorphology; erosion and sedimentation processes, hydrology; watershed assessment; erosion and sediment control BMPs; forest, ranch and rural roads; road construction, upgrading and closure*

QUALIFICATIONS:

CEO, Principal Geomorphologist, Pacific Watershed Associates Inc., 1989-present
Engineering Geologist, Redwood National Park, Arcata, CA, 1976-1989

Ph.D., Earth Resources (Geomorphology), Colorado State University, 1986
B.S., Geological Sciences, University of Washington, 1973

Washington Registered Geologist #2014
Washington Registered Engineering Geologist #2014

Adjunct Professor, Humboldt State University, 1988-present
Board of Directors, Humboldt County Resource Conservation District, Eureka, CA, 1994-2000
Scientific Advisory Panel, California Coastal Salmon Initiative, CA Resources Agency, 1996-97
California State Board of Forestry Task Force on forest road construction on landsliding, 1988-89
Coast Forest District Technical Advisory Committee to the California State Board of Forestry, 1976-1985

SUMMARY OF EXPERIENCE:

Dr. William Weaver has more than 35 years of professional experience in the fields of process geomorphology, surface water hydrology, watershed management and engineering geology. Since forming Pacific Watershed Associates, Inc. in 1989, his work has focused on forest geomorphology and the hydrologic and cumulative effects of land management and roads on forested watersheds, geomorphic processes and coastal ecosystems. Recently his work has concentrated on water quality protection, erosion control, and fisheries restoration achieved through sediment source investigations, as well as the evaluation, planning and designing of watershed rehabilitation and sediment control activities in steepland drainage basins. As the principal Engineering Geologist at Redwood National Park for 13 years, Dr. Weaver was instrumental in designing, initiating, and monitoring the internationally recognized watershed rehabilitation and erosion control program covering the park and the 280 mi^2 Redwood Creek watershed.

The watershed rehabilitation program at Redwood National Park was the first of its kind, and of its scale, to be attempted in North America and perhaps worldwide. It was a program designed to protect and restore the invaluable resources of Redwood National Park, a U.N. World Heritage Site, from the impacts of past and continuing timber harvesting and road building in steep forested lands along Redwood Creek. Dr. Weaver served as the principal Engineering Geologist for the National Park Service and acted as the lead scientist in planning, designing, organizing and implementing the restoration program from its inception in 1978 until 1989. Dr. Weaver was in charge of prioritizing, designing and implementing road restoration and erosion control projects within the 48,000 acre (19,500 ha) land acquisition from private industrial timberlands that the U.S. Congress added to the National Park in 1978. The allocated budget for the watershed restoration program was initially set at $33M dollars, but subsequently expanded to over $50M. The groundbreaking program focused on the assessment of erosion problems and water pollution threats largely derived from 250 miles of major and secondary forest roads that had been constructed on the newly acquired lands. These eroding and failing roads had been constructed on industrial forest lands in the lower portion of the 280 mi^2 Redwood Creek Watershed. At risk was Redwood Creek, a large coastal river with threatened and endangered fish species, the valuable ecosystem that supported those and other aquatic species, and world's tallest trees growing along its banks and on its floodplains.

Once the program was underway, Dr. Weaver assumed responsibility for developing and implementing a science-based monitoring program to evaluate the effectiveness and cost-effectiveness of each technique in the Park's watershed restoration and road rehabilitation program. Dr. Weaver brings from that extended multi-decade long experiment an unparalleled wealth of experience in everything from restoration planning; sediment source assessment; cost-effectiveness evaluation; the development, testing and routine implementation of specific techniques for controlling wildland erosion; effectiveness monitoring; as well as the oversight, contracting and administration of restoration projects. Initially springing out of this effort, Dr. Weaver has a long list of technical publications to his credit involving sediment source investigations, land management impacts, geomorphology, hydrology, watershed restoration, monitoring, and erosion control practices.

In 1989, Dr. Weaver left the National Park Service to form Pacific Watershed Associates (PWA). PWA was formed to bring the accumulated restoration experience developed on logged lands in Redwood National Park to managed forest and ranch lands in the private and public sector of the Western U.S.A., including small private landowners, industrial forest lands, tribal lands and federally owned watersheds where resource management strategies include continued utilization rather than simple preservation. Since then, PWA, under Dr. Weaver's leadership, has incorporated existing, tested restoration practices and strategies developed in northern California and elsewhere into an overall strategy for managing forest and coastal ecosystems that emphasizes protection of biological resources, attainment of water quality objectives, ecosystem restoration, and improved land stewardship practices. Because of the progressive and long term experience of the firm's principals (Dr. Weaver and Mr. Danny Hagans), PWA has been identified and recognized as an unmatched leader in evaluating, planning and designing watershed rehabilitation activities in steepland drainage basins for the purpose of watershed and water quality restoration, and fisheries protection and recovery. Their research and restoration experience encompasses upland drainage basins, riparian zones, fluvial and riverine systems, estuary and marsh habitat and coastal dune systems.

PWA has conducted watershed sediment source investigations on over 2000 mi^2 of tribal, federal, industrial and small private forest, ranch and rural subdivision lands in the Pacific Northwest. Under Dr. Weaver's leadership, his staff of 30 professionals and technicians have surveyed approximately 7,500 miles of forest roads in these watersheds and developed prioritized sediment reduction plans which include both road decommissioning as well as road storm-proofing (upgrading). Their work has been commissioned by state and federal agencies, local (county) governments, tribes, private companies, small landowners, and environmental organizations. Each year Dr. Weaver and his staff conduct numerous workshops and technical training sessions to educate landowners, land managers, agency staff and regulatory personnel on improved methods of land management and sediment control, especially related to roads, and to provide guidance on the protection of water quality and aquatic resources from various non-point sediment sources.

In 2008, Dr. Weaver's firm (Pacific Watershed Associates) received special recognition from the U.S. House of Representatives, the California State Senate, and the California Assembly for their work in watershed restoration and fisheries protection. PWA, and its founders Dr. William Weaver and Danny Hagans, was also recognized by *The Alliance for Sustainable Jobs and the Environment* as the 2008 Restoration Organization of the Year, representing the single organization to have "*achieved highest level of excellence and has had the most beneficial impacts on fisheries and watersheds in pursuit of the health and abundance*." The award cited their pioneering efforts to rehabilitate and restore the landscape of heavily damaged lands added to Redwood National Park, and to be "*at the forefront of a revolutionary approach to watershed restoration focusing on slope stabilization and recovery of hydrological integrity -- leading to prevention of stream sedimentation -- through methodical evaluation followed by careful and intensive corrective and/or constructive measures with heavy equipment*." ASJE recognized PWA and its founders, Dr. William E. Weaver and Danny K. Hagans, for "*…truly pioneering efforts. Their work, as well as that of a multitude of others who have adopted their techniques and systems, has kept millions of yards of soil material on slopes throughout Northern California and out of our precious rivers and streams. They continue to provide guideposts that are usable as well as an inspiration.*"

Dr. Weaver is co-author of the book *Experimental Fluvial Geomorphology* (1987) and has since authored a number of publications on geomorphology, watershed assessment techniques, and steepland erosion prevention practices. His most recent (2014) publication is a comprehensive, 416 page manual on forest, ranch, and rural roads, published in both English and Spanish (Handbook for Forest, Ranch and Rural Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Upgrading, Maintaining and Closing Wildland Roads). This book focuses on ways to construct and manage roads in wildland areas so they have a minimal impact on the environment and on downstream water quality. He is also principal author on many other publications including a chapter on forestland gully erosion included in U.S. Geological Survey Professional Paper 1454; the *Handbook for Forest and Ranch Roads*, a technical field guide commissioned by the California Dept of Forestry and Fire Protection and the U.S. Natural Resources Conservation Service; and *Part X: Upslope erosion inventory and sediment control guidance* from the California Department of Fish and Game *California Salmonid Stream Habitat Restoration Manual* (3rd edition). The California State Resources Agency calls PWA's 1994 publication, *Handbook for Forest and Ranch Roads*, the "definitive book on managing forest roads" that "belongs on every forest landowner's bookshelf." Three additional publications, *Storm- proofing Forest Roads*, *Sediment Treatments and Road Restoration*, and *Road Upgrading, Decommissioning and Maintenance - Estimating Costs on Small and Large Scales* provide a broad range of technical procedures for water quality and fisheries protection which have been applied to road upgrading, decommissioning, and erosion control in steep mountainous watersheds of the Pacific Northwest.

Dr. Weaver is a government-approved, leading expert and technical trainer in the fields of erosion and sedimentation, erosion control, water quality protection and the management of sediment sources in wildland watersheds and along public and private roads. He conducts numerous technical training sessions and workshops on erosion processes and non-point sediment control across the state each year. Dr. Weaver is recognized for his ability to prepare and present technical, science-based workshops on topics in a manner that is easily understood by both technical and non-technical audiences, including landowners, equipment operators, land managers, regulatory personnel, environmentalists, and other scientists and consultants.

Finally, Dr. Weaver has served on a number of task forces and technical committees appointed by the California State Board of Forestry to evaluate and recommend changes to the California Forest Practice Regulations covering timber harvest and road building on private forest lands throughout California. Dr. Weaver is considered a leading national expert in the field of steepland erosion processes, the impacts of road construction on watershed erosion and sedimentation processes, the effects of land management on watershed sediment yield, and the design and control of road-related erosion processes in steep, forested environments and wildland watersheds.

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ANNEX 3

Dr. Edmund D. Andrews, “An Evaluation of the Methods, Calculations, and Conclusions Provided By Costa Rica Regarding the Yield and Transport of Sediment in the Rio San Juan Basin,” July 2014

DISPUTE CONCERNING THE CONSTRUCTION OF A ROAD
IN COSTA RICA ALONG THE SAN JUAN RIVER

NICARAGUA v. COSTA RICA

An Evaluation of the Methods, Calculations, and Conclusions Provided By Costa Rica Regarding the Yield and Transport of Sediment in the Río San Juan Basin

Prepared for the Government of Nicaragua by:

Edmund D. Andrews, Ph.D.
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Boulder, Colorado

July 25, 2014

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I. EXECUTIVE SUMMARY

Costa Rica's analysis and conclusions regarding the construction of Route 1856 and its impact on the Río San Juan are underlain by a critical assumption. Prof. Thorne states at numerous points throughout his report that his assumed basin-wide sediment yield represents the natural condition of the Río San Juan. For example, at paragraph 6.45, Thorne characterizes the Río San Juan as having "naturally high concentrations of suspended sediment." Thorne's assertions, however, are not supported by citations from the scientific literature that would objectively establish the Río San Juan Basin's natural sediment yield. In fact, Thorne does not provide a single citation to support his conclusion that 1080 tons/km^2-yr is a "natural" sediment yield, or otherwise typical for a tropical drainage basin of similar precipitation, geology, forest cover, and relief. Published sediment yields from tropical river basins with undisturbed primary forests vary from 1 to 120 tons/km^2–year. The median reported sediment yield is about 20 tons/km^2-yr, and only a few studies have found sediment yields greater than 50 tons/km^2-year. Therefore, the sediment yields in the Río San Juan Basin prior to appreciable forest clearing and landscape disturbance were likely between 20 to 50 tons/km^2 per year, which would be 1/20th to 1/50th of Thorne's estimated basin-wide value of 1080 tons/km^2 per year. Current sediment yields across the Río San Juan Basin from Lake Nicaragua to the Caribbean Sea are not natural. They are, in fact, much greater than would be expected.

Costa Rica experienced one of the highest worldwide rates of forest clearing during the three decades after 1950. Deforestation maps prepared by MINAE, FONAFIFO (no year) and reproduced by Kleinn (2002) show that between 1950 and 1987 a substantial majority of the forested lands in the Río San Juan Basin were cleared. Numerous studies representing a wide range of climatic and geologic conditions have found that sediment yields typically increase 10- to 100-fold when an intact tropical forest is cleared, crops are planted and subsequently converted to pasture. Sediment yields in the range of 1000 or more tons/km^2-year are typical of deforested tropical drainage basins. Thorne's statement that the current basin-wide sediment yield to the Río San Juan is, on average about 1080 tons/km^2-yr is consistent with the scientific literature describing the expected sediment yields from disturbed tropical river basins. It must be concluded that the present sediment load of the Río San Juan is unnaturally elevated due primarily to deforestation and associated land disturbance in the Costa Rican parts of the basin.

Thus, current sediment yields from the Río San Juan Basin are most likely 20 to 50 times the rate that occurred prior to the substantial deforestation that began in about 1950.

Compared to the expected natural basin-wide contribution of sediment to the Río San Juan, the quantity of sediment associated with the construction of Route 1856 is quite substantial. Given the results cited in Table 1, one would expect that the Río San Juan would have carried between 170,000 to 420,000 tons per year before appreciable deforestation and other changes in land-use. Estimates determined by Costa Rica and Nicaragua of the additional sediment supplied to the Río San Juan by land degradation associated with Route 1856 range from 61,000 (Thorne) to 240,000 (Kondolf 2014) tons per year. Based upon this range of estimated sediment contributions, the quantity of sediment eroded from the Road corridor would have increased the total sediment load of the Río San Juan to the head of the delta by 15 to 140 percent over the expected natural condition.

Poor land-use practices in Costa Rica over recent decades have greatly increased the supply of sediment to the Río San Juan Delta area. Using the estimated mean annual supply of sediment to the head of the delta of about 13.7 million tons of suspended and bedload sediment, the average annual quantity of relatively coarse sediment that will tend to accumulate in the upstream portion of the delta in excess of what would have been deposited when sediment yields were truly natural is approximately 1.0 to 1.5 million m^3. The capacity of the Lower Río San Juan to carry flow and transport sediment has been greatly reduced over the past several decades. If only 10 percent of the relatively coarse sediment supplied to the delta is carried into the Lower San Juan channel, the expected aggradation rate due to the excess sediment – approximately 25,000 to 75,000 m^3 per year – within the first three kilometers of the Lower Río San Juan is in the order of 10 to 30 centimeters per year.

Costa Rica's analysis and conclusions focus primarily on two Río San Juan gages: the La Trinidad station and the Delta Colorado station. These gages were only operated for two full years and relatively few samples of suspended sediment were collected. It is apparent from the information presented in the Thorne Report and Annex 4 that Costa Rican hydrologists and water managers have determined that a couple of years of river flows and a few tens of suspended sediment samples are insufficient and cannot be relied upon to make informed decisions. Indeed, the common practices and standards applied by Costa Rican hydrologists and water managers to operate river gages elsewhere in the Río San Juan Basin are those that have been adopted worldwide. Two years of flow records and a few tens of suspended sediment samples are not sufficient to represent the magnitude and frequency of river discharges or calculate mean annual river sediment loads.

Prof. Thorne compares suspended sediment concentrations sampled at the La Trinidad and Delta Colorado gages and concludes that “[n]ot only is there no statistically significant difference between the pre- and post-Road suspended sediment rating curves, but Figure 26 reveals them to be practically identical.” (Thorne, para. 8.5.) The figure mentioned by Thorne was prepared using an improper statistical assumption, as well as by applying an approach inconsistent with Costa Rican practices elsewhere in the Río San Juan basin. A standard statistical test reveals there is only one chance in 100 that the observed suspended sediment concentrations at La Trinidad in 1974 to 1975 are the same as the concentrations that were observed at the Delta Colorado in 2011 to 2012. Prof. Thorne’s conclusion that the suspended sediment concentrations in the Río San Juan Basin have not changed over the past forty years is demonstrably false.

Coastal ecosystems are typically highly productive and diverse. As such, they are a valuable ecological resource and provide considerable economic value. Coastal ecosystems along the Caribbean coast of Central America are especially significant. Excessive rates of sediment deposition will impair and can substantially alter the structure and function of a coastal ecosystem. Today, coastal ecosystems worldwide are frequently impaired by excessive sedimentation. (Thrush and others, 2004). As little as 3mm of freshly deposited sediment is sufficient to impair the structure and function of estuarine and coastal ecosystems. Coral reefs throughout the Caribbean, including along the coast of Costa Rica, have been negatively impacted by large increases in the quantity of sediment eroded from the land surface and transported to the ocean. Elevated rates of sediment deposition directly onto the coral formation as well as increased turbidity have been associated with slower growth rates, changes in coral species, and reduced overall ecosystem productivity.

II. ABOUT THE AUTHOR

Edmund D. Andrews received a B.S. and M.S. degree in Geophysics from Stanford University and a Ph.D. degree in Geology from the University of California, Berkeley. He joined the U.S. Geological Survey in 1975 and served in various positions within the U.S.G.S's National Research Program until his retirement as Chief of the River Mechanics Project in July of 2009. Dr. Andrews had overall responsibility for the geomorphology, sediment transport, and surface water research programs within the U.S. Geological Survey from 1986 – 1990 and again from 1997 – 2002. Beginning in the 1980s, in addition to his work with the U.S.G.S., Dr. Andrews has held various faculty positions with the University of Colorado at Boulder, culminating in his appointment as a Research Professor and Fellow at the University's Institute for Arctic and Alpine Research in 2009.

The goal of Dr. Andrews' research has been to develop the analytical methods and approaches needed to maintain and restore the important geomorphic and ecological features of river channels. His research has focused primarily on the adjustment of river channels to alterations in streamflows and sediment supply. This research has concerned a wide variety of rivers affected by various natural and anthropogenic impacts. Notably, he was a principal investigator of the 1996 experimental flood released into the Colorado River through Grand Canyon National Park, consulted on the Yangtze River Basin in China, created the streamflow gaging network for the Long-Term Ecological Research facility in the McMurdo Dry Valleys of Antarctica, was appointed an advisor in river mechanics to the Canada-US International Boundary Commission and is a current member of the Platte River Independent Science Advisory Committee. Since 1988, Dr. Andrews has served as an expert witness in court proceedings to support the U.S. Government's work to establish instream flow water rights for National Forests and National Parks in several of the Western United States, as well as river sedimentation issues under the Federal Clean Water Act.

Dr. Andrews is currently a Research Professor Emeritus at the University of Colorado and is the Principal for Tenaya Water Resources, LLC.

III. INTRODUCTION

This report considers erosion and sedimentation in the Río San Juan Basin that straddles the border between Nicaragua and Costa Rica. The Río San Juan begins at Lake Nicaragua and flows southeast for approximately 200 kilometers to the Caribbean Sea. Along its course, tributaries from both Nicaragua and Costa Rica, draining approximately 11,000 km^2, enter the Río San Juan. Beginning just downstream of the Nicaraguan town of El Castillo and extending approximately 110 kilometers to the river mouth, the right bank of the Río San Juan forms the border between Nicaragua and Costa Rica.

This report will focus on three questions:

1) What was the likely natural range of sediment yields in the Río San Juan Basin *before* appreciable forest clearing, road building and other settlement activities?

2) What is the likely range of current sediment yields in the Río San Juan Basin given the *existing* land uses?

3) What is the relative significance of the sediment supplied to the Río San Juan from the Route 1856 corridor, compared to the natural, forested condition of the Río San Juan Basin?

To present the answers to these questions, this report will also evaluate the conclusions presented in a report prepared by Professor C. Thorne (2013). Dr. Thorne's report is Appendix A attached to the Counter-Memorial submitted December 19, 2013 by Costa Rica, and is henceforth referred to as "Thorne." This report will also assess the supporting document entitled "Report on Hydrology and Sediments for the Costa Rican River Basins Draining to the San Juan River" prepared by the Costa Rican Institute of Electricity (ICE), and attached as Annex 4 to the Counter-Memorial submitted December 19, 2013 by Costa Rica. It is henceforth referred to as "Annex 4."

IV. SEDIMENT YIELDS FROM UNDISTURBED AND DISTURBED TROPICAL RIVER BASINS

Any proper analysis of the impacts that the construction of Route 1856 has had and will have in the coming decades on the supply, transport and deposition of sediment to the Río San Juan must involve a comparison. The parties' estimates of the sediment contributed by Route 1856 to the Río San Juan range from 61,000 (Thorne) to 240,000 (Kondolf)[1] tons of sediment per year. The question is whether 61,000 to 240,000 tons per year is a relatively small or large amount of sediment in comparison to the natural sediment yield. The answer to this question depends largely upon the basin-wide sediment yield that is determined to be "natural."

Thorne refers to the analysis presented in Annex 4 to conclude that the Río San Juan currently transports about 9.13[2] million tons of sediment at the point about 20 kilometers upstream of the delta where the Río San Juan bifurcates. (See Thorne, Table 6.) He also states that the drainage area contributing sediment to the Río San Juan between Lake Nicaragua and the La Trinidad gage located near the head of the delta is about 8,420 km^2. (See Thorne, Table 2.)[3] Hence, Thorne's report would indicate that the sediment yield is approximately 1080 tons per square kilometer per year (hereinafter "tons/km^2-yr") from that portion of the basin between Lake Nicaragua and the head of the delta. Thorne then states at numerous points throughout his report that his assumed basin-wide sediment yield represents the natural condition of the Río San Juan. For instance, at paragraph 6.45, Thorne characterizes the Río San Juan as having "naturally high concentrations of suspended sediment." At paragraph 12.2, Thorne clarifies that he is comparing the inputs of Route 1856 to what he calls the River's "natural loads." Prof. Thorne then concludes that the sediment inputs from Route 1856 represent 2% or less of the Río San Juan's total load. (Thorne, p. 84.) Thorne's assertions, however, are not supported by references from the scientific literature that would objectively establish the Río San Juan Basin's natural sediment yield. In fact, Thorne does not provide a single citation to support his conclusion that

[1] G. Mathias Kondolf, "Erosion and Sediment Delivery to the Rio San Juan from Route 1856," July 2014 (hereinafter "Kondolf 2014").

[2] Thorne's Table 6 reports an annual average sediment yield of 9.133 million tons. The accuracy of sediment information is such that, at most, three significant figures are justified. Throughout this report, values of sediment yield and sediment load will be rounded to two or three significant figures depending on the expected uncertainty.

[3] The difference in drainage area between the La Trinidad and San Carlos gages.

1080 tons/km^2-yr is a “natural” sediment yield, or otherwise typical or reasonable for a tropical drainage basin of similar precipitation, geology, forest cover, and relief. I have also searched for such a study and have been unable to find one.

A. Sediment Yields from Undisturbed Forested Tropical Watersheds

To determine the Río San Juan Basin’s natural sediment yield, the proper procedure would be to evaluate and sum the observed sediment loads as measured on the tributaries to the Basin and the Río San Juan mainstem. Thorne seems to recognize that this would be the proper approach, but his analysis ignores and sidesteps significant problems with the available information. Thus, Thorne’s analysis focuses primarily on two river gages: 1) the La Trinidad station operated from 1973 to 1976, and 2) the Delta Colorado station operated from 2010 to 2013. (See Thorne, Table 2.) Neither the La Trinidad nor the Delta Colorado gage records cover the period prior to substantial landscape disturbance. The first hydrologic observations at these gages were initiated in 1974, well after substantial deforestation, construction of roads and other landscape destabilization on the Costa Rican tributaries to the Río San Juan. Furthermore, both river gage records are short – only about two years. Given that the river gaging stations were only operated briefly and decades after appreciable changes in land-use throughout the Costa Rican tributaries to the Río San Juan, these records cannot be relied upon to represent, even approximately, the natural condition. Likewise, the summary of sediment loads presented in Annex 4 for 12 river gages located on tributaries to the Río San Juan cannot be used to infer natural sediment yields because all of these gages were established after 1967, well after substantial changes in land-use.

Without the benefit of useful gage records from the Río San Juan Basin to analyze the Basin’s natural sediment yields, the best recourse is to search for data from comparable forested tropical river basins. I undertook a search of the scientific literature to compile information from published estimates of sediment yields from undisturbed tropical river basins. These studies and reported sediment yields are listed in Table 1.

The number of available hydrologic records describing sediment transport in undisturbed tropical river basins is not large. In selecting the studies to include, I have relied on the authors’ characterization that the basins were essentially undisturbed. Nevertheless, some of the authors noted that even these river basins were not entirely pristine, and one might therefore suspect that the reported sediment yields are increased to some extent over the natural conditions. (See

Douglas, 1967.) The available studies report sediment yields from forested tropical river basins with a wide range of precipitation, geology and topographical relief, including basins that, like the Río San Juan basin, contain areas of volcanic soil, steep slopes, and receive significant rainfall.

Table 1. Published sediment yields from tropical river basins with undisturbed forest vegetation.

Study	**Location (Number of River Basins)**	**Sediment Yield ($tons/km^2$-year)**
Douglas (1967)	Australia (26)	2 to 25
Dunne (1979)	Kenya (4)	15 to 25
Brown and others (1998)	Puerto Rico (1)	114
Hewawasam and others (2003)	Sri Lanka (11)	13 to 30
Sidle and others (2006)	Southeast Asia (numerous sites)	1 to 120

As shown in Table 1, the reported sediment yields from tropical river basins with undisturbed primary forests vary from 1 to 120 $tons/km^2$–year.[4] The median sediment yield shown in Table 1 is about 20 $tons/km^2$-yr, and only a few studies have found sediment yields greater than 50 $tons/km^2$-year. Thus, while it is arguably possible that the basin-wide sediment yield in the Río San Juan may have been somewhat more than 50 $tons/km^2$-year, and perhaps as high as 120 $tons/km^2$-year before widespread deforestation, such a rate would be unusual based upon the studies published in the scientific literature. Therefore, the sediment yields in the Río San Juan Basin prior to appreciable forest clearing and landscape disturbance were likely to fall between 20 to 50 $tons/km^2$ per year, which would be 1/20[th] to 1/50[th] of Thorne's estimated basin-wide value of 1080 $tons/km^2$ per year.[5]

[4] Sediment yields tend to increase with precipitation and decrease with drainage area. It is likely that some, and perhaps most of the drainage basins represented in Table 1 receive less precipitation and/or have smaller drainage areas than the Rio San Juan tributaries flowing out of Costa Rica. Both trends are relatively weak, however, and would offset each other.

[5] See related discussion in section V(D), where it is also shown that the estimate of 1080 $tons/km^2$-year of sediment yield was based on observations gathered during two years of relatively low river flows and well below average sediment transport, and that this deficiency has a significant impact on the comparison of sediment yields from the years after land-use disturbance to the estimated long-term average sediment yields,

B. Impact of Land Use on Sediment Yield

Scientific studies over the past five decades have repeatedly demonstrated across a wide range of landscapes that land use is the single most important factor affecting sediment yields. Each of the five publications cited in Table 1 is focused primarily on the increase in sediment yield following changes in land use. While other factors, such as precipitation, bedrock geology, soils, and topographic relief are commonly found to also be important and well correlated with sediment yield, these factors remain relatively stable over time, while changes in land use can have a dramatic and immediate influence on the rate of sediment erosion and the resulting yield of sediment from a drainage basin. (Milliman and Syvitski, 1992).

Among the most common and widely studied changes in land use is the conversion of tropical forests to agriculture and pasture. (See Bruijnzeel, 1990; Sidle and others, 2006). The sediment yields from a drainage basin typically increase 10- to 100-fold when an intact tropical forest is cleared, crops are planted and subsequently converted to pasture when the soil fertility is exhausted. (See, e.g. Hewawasam (2003); Sidle and others, 2006.) The clearing of tropical forests for trails and roads, although the total affected acreage may be less than pasture conversion, has been found to create even larger sediment yields which are sustained over time if the road is not properly constructed and maintained. (Id.)

Costa Rica experienced one of the highest worldwide rates of forest clearing during the three decades after 1950. Leonard (1986) estimated that the annual rate of deforestation was nearly 4 percent of the total Costa Rican land area between 1950 and 1984. Forest clearing was promoted by a government policy that made forest clearing a prerequisite to obtaining land title. (Kleinn, 2002.) The results of one study published by the World Bank found that the percentage of forest cover in Costa Rica declined from over 65 percent in 1950 to slightly less than 30 percent in 1988. (Lutz and others, 1993.) In another study, Sader and Joyce (1988) concluded that the remaining undisturbed forest in 1988 was less than 20 percent. Deforestation maps prepared by MINAE, FONAFIFO (no year) and reproduced by Kleinn (2002) show that between 1950 and 1987 a substantial majority of the forested lands in the Río San Juan Basin were cleared. Rosero-Bixby and Palloni (1998) found that the rate of forest clearing was especially high in areas drained by the Río San Juan over the period 1973 to 1983. The estimates by these several studies may include both primary, undisturbed forests as well as some second-growth forests that may not be recognizable in a satellite image as having been disturbed. Thus, while the studies differ somewhat in details, they agree on the overall change, and demonstrate a very rapid rate of deforestation after 1950 in Costa Rica, including in the Río San Juan Basin.[6] These analyses show that by 1990, only a small portion of the original primary forest remained.

C. Sediment Yields from Tropical River Basins Affected by Forest Clearing and Road Construction

The evidence demonstrates that substantial deforestation has occurred in the Río San Juan Basin in the past six decades. This deforestation should be expected to have produced greatly increased sediment yields. The studies cited in Table 1 also provide estimates of sediment yield from disturbed tropical river basins. Although these studies cover a wide range of deforestation as well as hydrologic, geologic, and topographic conditions, they have all found that forest clearing and road building in tropical river basins will increase sediment yields 10- to 100-fold. In fact, the studies show that accelerated erosion and sediment yields of several hundred to more than ten thousand tons per square kilometer per year are typical. (See Douglas (1967), Dunne (1979), Hewawasam (2003), and Sidle and others (2006).) Thus, Thorne's statement that the current basin-wide sediment yield to the Río San Juan is, on average about 1080 tons/km^2-yr is consistent with the scientific literature describing the expected sediment yields from disturbed tropical river basins. It must be concluded that the present sediment load of the Río San Juan is unnaturally elevated due primarily to deforestation and associated land disturbance in the Costa Rican parts of the basin.

D. Sediment Impact of Route 1856

Compared to the expected natural basin-wide contribution of sediment to the Río San Juan, the quantity of sediment associated with the construction of Route 1856 is quite substantial. Given the results cited in Table 1, one would expect that the Río San Juan would have carried between 170,000 to 420,000 tons per year before appreciable deforestation and other changes in land-use. Estimates determined by Costa Rica and Nicaragua of the additional sediment supplied to the Río San Juan by land degradation associated with Route 1856 range from 61,000 (Thorne)

[6] Deforestation has also occurred in the Nicarguan tributary basins. However, because the Costa Rican basins represent about 83 percent of the drainage area contributing sediment to the Rio San Juan (see Thorne, Table 3) and the extent of deforestation is greater, I have focused on the Costa Rican basins in this analysis.

to 240,000 (Kondolf 2014) tons per year. Based upon this range of estimated sediment contributions, the quantity of sediment eroded from the Road corridor would have increased the total sediment load of the Río San Juan to the head of the delta by 15 to 140 percent over the expected natural condition. The estimated range of sediment eroded from the Route 1856 corridor is significant given the inherent uncertainties. In any case, the construction of Route 1856 has contributed a very substantial amount of sediment to the Río San Juan compared to the circumstances prior to deforestation.

The additional sediment is not contributed uniformly along the river corridor. A majority of the sediment eroded from the Route 1856 corridor enters the Río San Juan in the reach that begins just below El Castillo and ends 41 kilometers downstream at the confluence of the Río San Carlos. Given the smaller contributing drainage area in this upstream section of the river, the natural sediment load would have been considerably less than the 170,000 to 420,000 tons per year estimated for the entire river basin. Thus, the relative increase in the river's sediment load due to sediment eroded from the Route 1856 corridor through this reach of the river would have been greater than for the entire basin.

V. EVALUATION OF SEDIMENT ISSUES IN REPORTS SUBMITTED BY COSTA RICA

Thorne offers several opinions concerning sediment erosion and transport in the Río San Juan Basin. In forming his opinions, he relies extensively on Annex 4. The following portion of this report will evaluate the information Professor Thorne relies upon and the validity of his opinions. Several of Thorne's opinions are based upon insufficient or doubtful hydrologic information or are unsupported by the available information as collected at Costa Rican river gages. In addition, significant conclusions reached by Prof. Thorne rely upon inconsistent and faulty analyses. This section will evaluate and discuss several conclusions presented in the Thorne report.

A. Overview of River Gages

A brief description of the information collected at a river gage and the analysis of this information to determine the magnitude of river flows and sediment transport over a period of years will provide some helpful background for the following evaluation. The basic operations of a river gage and the procedures for the sampling of sediment transport are well-established and broadly applied worldwide.

1) *River Stage Recorder*. The primary function of a river gage is to measure and record the water surface elevation, commonly referred to as the river "stage." Various types of instruments such as floats and pressure sensors are deployed to measure the stage. River stage, time and date are recorded at desired intervals of time, e.g. every one, five, fifteen or thirty minutes, as a time-series of river stage.

2) *Measurement of River Discharge*. River discharge is the volume of water flowing past the gage location per second, i.e. cubic meters per second or m^3/sec. It is measured periodically, over as wide a range of river stages as possible. River stage and discharge are then correlated, graphically, mathematically or both, to define the stage-discharge relation for the gage. The stage-discharge relation may change over time as the characteristics of the river reach are altered. Typically, the river discharge will be measured a few to dozens of times during a year to ensure that the stage-discharge relation is current and accurate.

3) *Calculation of River Discharge*. The time-series of river discharges is determined by combining the recorded time-series of river stage with the stage-discharge relation. The time-series of river discharge is then integrated over an increment of time (day, month, year) to give the volume of water runoff. Mean discharge is the volume of runoff divided by an increment of time, i.e. cubic meters per second or m^3/sec.

4) *Fluvial Sediment Transport*. Sediment particles are transported either suspended within the water column – called the suspended sediment load – or in more or less continuous contact with the river bed – which is called bedload. The mode of sediment transport within the river cross-section depends upon the intensity of turbulence and the settling velocity of the sediment particles, as influenced by particle size, shape and density. At a given river discharge, sediment particles with settling velocities that are relatively small compared to the turbulent intensities will be suspended in the flow of the river, while the sediment particles with settling velocities that are relatively large compared to the turbulent intensities will be rolling or bouncing over the river bed.

The total sediment load of a river will be mainly suspended sediment – 85 percent or more – except in rare circumstances (Judson and Ritter, 1964; Vanoni, 1976.) The bedload transport rate at a given river discharge may be calculated using an equation that relates the fluid forces acting on the river bed and the gravitational forces resisting motion or by collecting a sample of sediment particles in motion.

B. Sampling of Suspended Sediment Concentration

The concentration of suspended sediment in a river cross-section at a given moment varies appreciably from bank to bank and from river bed to surface. The concentration will typically be highest close to the river bed near the center of the channel, and will decrease upward to the river surface and outward towards the river bank. The methods and equipment needed to collect a representative sample, i.e. one for which the concentration of the sample is the same as in the river cross-section, were developed several decades ago. (See Edwards and Glysson, 2005.) They are well established and have been adopted worldwide. This method involves collecting discharge-weighted samples of the flow at many verticals across the river channel. For a relatively wide channel, such as exists in the Río San Juan, 20 to 30 sample verticals are necessary to obtain a representative sample of the river's sediment load.

This overview of sediment load calculations is presented to describe the importance of the record of river discharges and well-defined relations between the suspended and bedload sediment transport and river discharges. The calculation of sediment load depends upon having sufficient and representative information to define both the magnitude and frequency of river flows as well as associated flux of sediment. The remaining portion of this report will describe numerous examples of insufficient and poor quality hydrologic information, incorrect and improper analysis, and unsupported or wrong conclusions contained in Thorne and Annex 4. The discussion will necessarily be detailed and specific, as Costa Rica has attempted to characterize hydrology and sediment transport in the Río San Juan Basin with considerable specificity. Repeatedly, Thorne states that some given result is reliable and forms his opinion accordingly, when the opinion is demonstrably faulty or unsupported by the available hydrologic information.

C. Representative Records of River Discharge and Sediment Transport

It is worthwhile to begin simply by considering certain tables from the Thorne report, which I have reproduced in this report as Table 2 and Table 3 below. Table 2 provides summary information on four Río San Juan river gages and 12 tributary gages located in the Costa Rican parts of the basin. Thorne's analysis and conclusions focus primarily on two gages shown in this Table, the La Trinidad (01-03) and Delta Colorado (11-04). The period of record for each gage is shown in Table 2. The difference in record length for the La Trinidad and Delta Colorado gages compared to the 12 other Costa Rican operated tributary gages is striking. The 12 tributary gages have been operated for an average of 29 years; all but one have been operated for 10 or more years. The La Trinidad and Delta Colorado gages, however, were only operated for 2 complete years of record each.[7] Operating a river gage and compiling the record of flows requires substantial resources, and is expensive. A water management authority would not pay to operate a river gage for ten or more years, if just a couple of years would provide adequate information to understand the flow regime at a given location. The length of flow records shown for these 12 tributary gages demonstrates that Costa Rican hydrologists have found that ten or more years of record are necessary for statistical value and therefore are worth the substantial cost of operation. Thus, as demonstrated by Costa Rica's own practices, the two years of flow records available at the La Trinidad and Delta Colorado gage are insufficient to provide reliable information upon which to base Thorne's conclusions.

Similarly, summary information describing suspended sediment transport at the La Trinidad and Delta Colorado gages as well as the 12 Costa Rican tributary gages is shown in Table 3. A range of 25 to 338 suspended sediment samples have been collected at each of the several gages. More than 100 suspended sediment samples have been collected at 9 of the 12 river gages. It is evident that Costa Rican hydrologists have determined that 100 or more sediment samples is worth the effort and expense of collection to produce a reliable result. Yet Thorne concludes that 12 samples at the La Trinidad and 31 samples at Delta Colorado provide sufficient data to support his opinions. (See Thorne, page 67).

[7] Only complete years of gage record will be used for comparison, in order to avoid bias. A list of daily mean discharges recorded at the Delta Colorado gage (11-04) provided on an Excel spreadsheet attached to Annex 4 indicates that the gage was operated from December 17, 2010 to July 31, 2013. Accordingly, the gage record covers two complete calendar years of observation – 2011 and 2012. Likewise, Prof. Thorne reports that the records from La Trinidad were collected between January 1974 and March 1976 – two complete calendar years of observation. (Thorne, para. 6.28.)

Table 2. Copy of Thorne Table 2

Table 2. Gauging stations on the Río San Juan - Colorado system and its Costa Rican tributaries (from ICE Report).

Station code	Station Name	River	Basin	Drainage Area (km^2)	Period of Record	Mean Annual Discharge ($m^3 s^{-1}$)	Active to date
01-01[a]	San Carlos	San Juan	San Juan	30 306[c]	1965-1986[c]	297[c]	No
01-02[a]	El Castillo	San Juan	San Juan	32 819[d]	1971-1981 1997-1998[b]	422[b]	No
01-03	La Trinidad	San Juan	San Juan	38 730[e]	1973-1976[e]	1123	No
11-04	Delta Colorado	Colorado	San Juan	-	2010-2013	1026	Yes
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	845	1968-1999	113	No
12-04	Veracruz	Toro	Sarapiquí	191	1971-2013	26	Yes
12-05	Bajos del Toro	Toro	Sarapiquí	73	1985-1996	6.7	No
12-06	Toro	Toro	Sarapiquí	41	1993-2013	4.4	Yes
12-11	San Miguel	Volcán	Sarapiquí	59	1998-2002 2010-2013	11	Yes
12-13	Río Segundo	Segundo	Sarapiquí	17	1999-2013	2.7	Yes
14-02	Jabillos	San Carlos	San Carlos	552	1963-2013	51	Yes
14-04	Terrón Colorado	San Carlos	San Carlos	1556	1968-2008	166	No
14-05	Peñas Blancas	Peñas Blancas	San Carlos	293	1968-2013	35[f]	Yes
14-20	Pocosol	Peñas Blancas	San Carlos	124	1980-2013	19	Yes
16-02	Guatuso	Frío	Frío	253	1969-2013	28	Yes
16-05	Santa Lucía	Venado	Frío	34	1982-2013	3.9	Yes

[a]Stations installed, coded and operated by the INETER of Nicaragua. [b]INETER (2001). [c]INETER (2002). [d]INETER (2006). [e]ICE (1973). [f]Since 2002 the discharges are regulated by the Peñas Blancas hydropower plant.

Table 3. Copy of Thorne Table 4

Table 4. Suspended sediment gauging stations along the main stream Rio San Juan and in Costa Rican tributary basins (from the ICE Report).

Station code	Name	Basin	River	No. samples	Sampling period	Ave. Annual Suspended load ($t\ yr^{-1}$)
01-03	La Trinidad	San Juan	San Juan	12	1974-1976	7 995 000
11-04	Delta Colorado	San Juan	Colorado	31	2010-2013	5 981 000[a]
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	264	1970-1998	165 500
12-04	Veracruz	Sarapiquí	Toro	285	1972-2012	101 000
12-05	Bajos del Toro	Sarapiquí	Toro	137	1985-2001	50 000
12-06	Toro	Sarapiquí	Toro	117	1995-2010	20 500
12-11	San Miguel	Sarapiquí	Volcán	47	1998-2010	23 000
12-13	Río Segundo	Sarapiquí	Segundo	25	1999-2009	1 800
14-02	Jabillos	San Carlos	San Carlos	338	1967-2011	600 000
14-04	Terrón Colorado	San Carlos	San Carlos	53	1998-2009	1 300 000
14-05	Peñas Blancas	San Carlos	Peñas Blancas	308	1970-2011	157 000
14-20	Pocosol	San Carlos	Peñas Blancas	278	1980-2012	358 000
16-02	Guatuso	Frío	Frío	361	1970-2012	60 800
16-05	Santa Lucía	Frío	Venado	153	1984-2011	8 100

[a]Note: this is the average annual suspended load of the Río Colorado downstream of the Delta.

It is apparent from the information in Tables 2 and 3 that Costa Rican hydrologists and water managers have determined, as demonstrated by their choices, that a couple of years of river flow and a few tens of suspended sediment samples are insufficient and cannot be relied upon to make informed decisions. Indeed, the common practices and standards applied by Costa Rican hydrologists and water managers are those that have been adopted worldwide. Two years of flow records and a few tens of suspended sediment samples are not sufficient to represent the magnitude and frequency of river discharges or calculate mean annual river sediment loads.

Despite these problems with the La Trinidad and Delta Colorado stations, Thorne focuses the Costa Rican analysis primarily on these gages. The La Trinidad gage is located approximately 20 kilometers upstream of the delta area, whereas the Delta Colorado gage is located on a distributary channel in the delta which now carries most of the basin runoff. Based upon calculations of annual suspended sediment load conducted at these gages by ICE and reported at Annex 4, Thorne concludes that sediment loads in the Río San Juan have not changed appreciably between the two periods of record, 1973-1976 and 2010-2013. (See Table 3.) Indeed, Thorne's result appears to suggest that the annual suspended sediment loads may have *decreased* over time. The following evaluation, using information from Annex 4, will demonstrate that this conclusion is wrong and presents a misleading view of the actual circumstances.

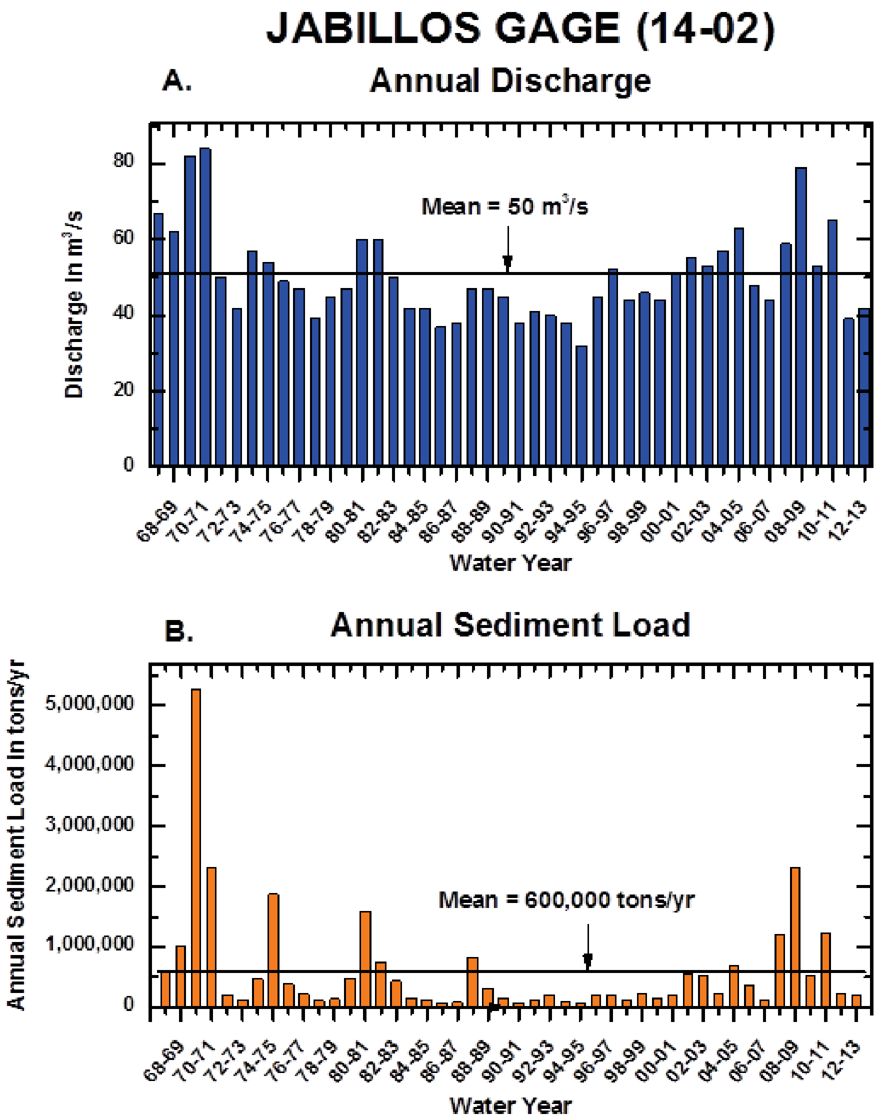
D. Annual River Discharge and Sediment Loads at the Jabillos Gage

In order to understand the deficiencies of the La Trinidad and Delta Colorado river gage records that arise from the very short period of observations, it is helpful is examine a much longer gage record, including extensive sampling of suspended sediment transport. The time-series of annual river discharges and annual suspended sediment loads recorded at the Jabillos gage, collected by Costa Rica in the San Carlos basin, are shown in Figure 1. The plotted values are listed on page 195 of the Costa Rican Annex 4. The Jabillos gage was selected as an example because it has the longest record, the largest drainage area, and most samples of suspended sediment concentrations (338) among the currently active gages located on Costa Rican tributaries to the Río San Juan. The annual mean discharge recorded at the Jabillos gage is 50 m^3/sec. (See Part A of Figure 1.) Over the period of record that exceeds forty years, annual river discharges have varied from 84 m^3/sec in 1971 to 32 m^3/sec in 1995.[8] All of the observed annual discharges are within the range of 0.6 to 1.7 times the long-term mean.

Annual suspended sediment loads reported for the Jabillos gage are shown in Part B of Figure 1. Again, over the 40 year period of record, the annual suspended sediment load has varied widely, from 5.28 million tons in 1970 to just 51,000 tons in 1995, with a long-term

[8] The year-to-year variations in the mean annual river discharge are primarily due to variation in annual precipitation across the drainage basin contributing runoff.

Figure 1. Observed annual river discharges (A) and sediment loads (B) at the Jabillos gage (14-02) from 1967 to 2013.



average of approximately 600,000 tons. Annual suspended sediment loads vary over 100-fold, ranging from 0.08 to 8 times the long-term mean. It is evident that annual suspended sediment loads are much more variable than the annual mean river discharges. Put another way, a relatively small percentage change in annual river discharge results in a much larger percentage change in annual suspended sediment load. For example, an annual river discharge that is ten percent greater than the long-term mean, i.e. 1.1 times the mean, would be expected to transport a sediment load 53 percent greater than the mean, i.e. 1.53 times the long-term mean value.

There is another remarkable characteristic of annual river flows evident in Figure 1A. Above average annual river flows tend to follow a prior year of above average river flows. Similarly, below average annual river flows tend to follow a prior year of below average river flows. This phenomena is called persistence. Persistence is a common feature of hydro-meteorological time-series, and reflects both that weather patterns tend to be stable for a period of time and also that water is stored within a river basin from one year to the next. Without persistence, annual runoff from one year to the next would be totally independent. Persistence is also apparent in the time-series of annual sediment loads. Because of persistence, hydrologic records covering just a few years are much more likely to deviate from the long-term mean than one would otherwise expect – in other words, if a record only reflects two years, it is likely that the recorded flows will be similar to each other, while a longer period of record is more likely to demonstrate the full range of conditions that exist within a watershed.

The Jabillos gage illustrates the variability of annual flows and sediment loads and shows how misleading just two years of gage record can be. The Jabillos gage record covers the years when both the La Trinidad and Delta Colorado gages were operated and therefore provides a basis on which to compare the annual river discharges and sediment loads reported for the years 1974 and 1975 (La Trinidad) and the years 2011 and 2012 (Delta Colorado) to the long-term mean value observed at the Jabillos gage. Annual river flows recorded at the Jabillos gage were 54m^3/sec in 1974 and 49 m^3/sec in 1975, versus 39 m^3/sec in 2011 and 42 m^3/sec in 2012. (See Part A of Figure 1.) The long-term mean annual flow recorded at the Jabillos gage is 50m^3/sec. Thus, annual river discharges recorded at the Jabillos gage were slightly above average (103 percent of the long-term mean) during 1974 and 1975 when the La Trinidad gage was operated, and significantly below average (81 percent of the long-term mean) during 2011 and 2012 when the Delta Colorado gage was operated.

A comparison of the annual suspended sediment loads recorded at the Jabillos gage shows an even greater difference between the two 2-year periods, as one would expect. Annual suspended sediment loads determined at the Jabillos gage were 1,870,000 tons in 1974 and 386,000 tons in 1975 versus 231,000 tons in 2011 and 203,000 tons in 2012. (See Part B of Figure 1.) The long-term mean annual suspended sediment load observed at the Jabillos gage is 600,000 tons/yr, whereas the average annual sediment load was 1,130,00 tons during 1974 and 1975 and only 217,000 tons/yr during 2011 and 2012. It is apparent that hydrologic conditions in the Río San Juan Basin were quite different during the two periods that the La Trinidad and the Delta Colorado gages were operated, nearly 40 years apart. They should not be compared directly or serve as the basis for conclusions.

Thorne acknowledges that the calculated sediment loads for the La Trinidad and Delta Colorado gages are "based on a small number of samples over short (two to three year) periods." (Thorne, para. 8.11.) Furthermore, he recognizes that "the post-Road period has been drier than usual." (Thorne, para. 8.12.) In neither instance, however, does he attempt to account for the deficiency or qualify his opinion.

E. Normalized Annual River Discharges and Sediment Loads for the La Trinidad and Delta Colorado Gages

To enable useful comparisons of record, the annual river discharges and suspended sediment loads reported for the La Trinidad and Delta Colorado gages must be corrected (normalized) to reflect the long-term hydrologic conditions in the Río San Juan Basin. Rather than relying on just one long river gage record, e.g. the Jabillos gage, it is preferable to expand the comparison to include all of the river gages in the Río San Juan Basin with more than a decade of observed flows and sediment loads that were operated simultaneously with either the La Trinidad or Delta Colorado gages. This will maximize the amount of record for analysis. Table 2 lists 5 river gages, including the Jabillos gage, which were operated in 1974 and 1975. Similarly, there are 9 river gages, including the Jabillos gage, with observations for over a decade or more that were operated in 2011 and 2012. Annual mean river discharges and suspended sediment loads for all of the long-term gages are listed in Annex 4 at pages 182 to 205. For the 5 gages operated during the years 1974 and 1975, I have calculated the average annual river flows and sediment loads for the years 1974 -1975 as well as for the entire period of record when these gages were operated. Similarly, for the 9 gages operated during the years 2011 and 2012, I have calculated the average annual river flows and sediment loads for the years 2011 and 2012 as well as for the entire period of record when these gages were operated. The results are summarized in Table 4A for 1974-1975 and Table 4B for 2011-2012.

Table 4A. River discharges and sediment loads in the Río San Juan Basin during the years 1974-1975 compared to the long-term mean

River Gage	**Mean Annual River Discharge** (m^3/sec)		**Ratio**	**Mean Annual Suspended Sediment Loads** (Tons/yr)		**Ratio**
	1974 & 1975	Period of Records		1974 & 1975	Period of Records	
Puerto Viejo Veracruz Jabillos Penas Blancas Guatuso	262	254	1.03	1,760,000	1,080,000	1.63

Table 4B. River discharges and sediment loads in the Río San Juan Basin during the years 2011-2011 compared to the long-term mean

River Gage	**Mean Annual River Discharge** (m^3/sec)		**Ratio**	**Mean Annual Suspended Sediment Loads** (Tons/yr)		**Ratio**
	2011 & 2012	Period of Records		2011 & 2012	Period of Records	
Veracruz Toro San Miguel Río Segando Jabillos Penas Blancas Pocosol Guatuso Santa Lucia	152	179	0.85	606,000	1,330,000	0.46

The basin-wide comparison shows that during the years 1974 and 1975 river flows were 103 percent of the expected mean and suspended sediment loads were 163 percent of the expected mean. During the years 2011 and 2012, annual river flows were only 85 percent of the expected basin-wide mean and suspended sediment loads were just 46 percent of the expected basin-wide mean. Consequently, one would expect that the long-term mean annual sediment load at the La Trinidad gage would have been substantially less than the reported 1974-1975 value of 7,995,000 tons, whereas the long-term mean annual sediment load at the Delta Colorado gage would be substantially more than the 2011-2012 reported value of 5,981,000 tons/year. (See Table 3.) Given the hydrologic condition that existed across the Río San Juan Basin, one would expect that the long-term mean annual suspended sediment load would be about 2.2 times the reported value for the period 2011-2012. Correcting the reported values to reflect the hydrologic conditions across the Río San Juan Basin when the two gages were operated, one would expect that the long-term mean annual suspended sediment loads at the La Trinidad gage would be approximately 4.90 million tons per year, and 13 million tons per year at the Delta Colorado gage.[9]

F. Portion of the Río San Juan Flowing into the Delta Colorado Channel

Thorne concludes that "roughly 90% of the Río San Juan discharge flows into the Río Colorado, while roughly 10% flows into the Lower Río San Juan. (Thorne, para. 8.9.) To reach this conclusion, he makes another significant error by comparing average annual discharges recorded at the La Trinidad and Delta Colorado gages without taking into account basin-wide differences in runoff during the respective periods when these gages were operated. Thorne compares the reported mean annual flows at the La Trinidad gage, 1123 m3/sec, for the years 1974-75 with the mean annual flows at the Delta Colorado gage, 1026 m3/sec, for the years 2011 and 2012. He then concludes that the difference of 97m^3/sec represents the quantity of flow in the Río San Juan channel through the delta. (See Thorne, page 67.) This is a significant oversight. Considering all of the gages operated in 1974 and 1975, basin-wide river flows in the Río San Juan were about 3 percent *greater* than average. (See Table 4A.) Considering all of the tributary gages operated in 2011 and 2012, basin-wide river flows in the Río San Juan Basin were 15 percent *less* than average. (See Table 4B.) Accordingly, when normalized to the long-term basin-wide hydrology, one would expect that the mean annual discharge was 1090 m^3/sec at the La Trinidad gage for the years 1974 and 1975, and 1210 m^3/sec at the Delta Colorado gage for the years 2011 and 2012.

Quite simply, the relative portions of annual flow in the delta distributary channels cannot be determined with any confidence using the La Trinidad and Delta Colorado gage

[9] The apparent similarity in suspended sediment loads at the La Trinidad and Delta Colorado is solely an artifact of the hydrologic conditions during the brief periods, nearly 40 years apart, when these gages were operated.

records. The available flow records provide no information or insight regarding the division of flow between the two major delta channels, the Río San Juan and the Delta Colorado. These may, in fact, be the only available information. But this circumstance does not justify overstating or reaching for conclusions that are not supported.

G. Calculation of Bedload Transport

Bedload is the portion of a river's total sediment load that hops, bounces, and rolls along the river bed. Although bedload typically represents only a few to several percent of the total sediment load, and rarely more than 15 percent, bedload is the first material to accumulate on the river bed when the flow slackens. It is bedload and, to a lesser extent, the coarsest suspended sediment that is deposited in the distributary channels of the Río San Juan Delta. As will be discussed in more detail below, the relatively coarse sediment transported as bedload in the Río San Juan is primarily responsible for the growth of sandbars and the restriction of navigation in the delta channels.

The bedload transport rate at a given river discharge may be calculated by collecting a sample of sediment particles in motion. The ICE report indicates that samples of bedload transport have been collected at three locations: the mouth of the Río Sarapiqui, the mouth of the Río San Carlos, and at the Delta Colorado gage. No information about the sampled bedload transport rates is presented, except for graphs showing bedload particle size in Annex 4, pages 210 to 271. The particle size information, however, is nearly worthless without the associated hydraulic conditions and sampled transport rate.

In the absence of proper sampling, bedload can be calculated using an equation. The transport of bedload sediment is directly related to the fluid forces acting on the river bed. This relation is formally expressed as a bedload function or equation. Many bedload equations have been derived over the past 130 years based upon fluid mechanical principles and laboratory flume experiments. (See Vanoni, 1976.) Calculated bedload transport rates are particularly sensitive to errors or uncertainty in the fluid forces acting on the river bed at a given discharge. Fluid forces depend on hydraulic characteristics, such as flow depth, velocity, the presence of bedforms, and river slope. Relatively small errors in the estimation of fluid forces, e.g. +/- ten percent, will result in much larger errors in the calculated bedload transport rate, which varies rapidly as a function of the fluid forces. The effective exponent of the bedload transport rate versus fluid forces decreases from about 14 as river bed sediment begins to move and approaches a value of 1.5 at very high transport rates. Thus, a +/- 10 percent error in the calculation of fluid forces will result in errors of a few tens up to a few hundreds of percent in the calculated bedload transport rate.

H. River Slope

Thorne divided the Río San Juan into geomorphically similar reaches and reported reach length, change in elevation, and average river slope for the selected reaches. In Table 5, shown below, the first 4 columns reproduce information presented in Thorne's Table 1. River slope is defined as the change in water surface elevation divided by the measured length of channel. The values of river slope as reported by Thorne, shown in red, column 4, are computed incorrectly. The correct values of river slope, given the reported change in elevation and length of channels are shown in column 5.

REACH	REACH LENGTH (km)	CHANGE IN ELEVATION (m)	SLOPE AS REPORTED BY Thorne (m/m)	SLOPE (m/m)
Río Frio – Río Pocosol	52.86	6.5	0.007	0.00012
Río Pocosol- Río San Carlos	52.67	7.7	0.008	0.00015
Río San Carlos- Río Sarapiqui	39.86	6.9	0.010	0.00017
Río Sarapiqui- Delta	22.04	3.8	0.010	0.00017
Delta – Caribbean Sea	32.35	5	0.009	0.00015

Table 5. Comparison of river slopes reported by Thorne for selected reaches of the Río San Juan and the correct values.

Thorne does not appear to have utilized his incorrect slope values to calculate the rate of bedload transport. Instead, he relies on values calculated by ICE. An Excel spreadsheet attached to Annex 4 describes the calculation of bedload transport rates at the Delta Colorado gage using the Einstein bedload equation. (See Einstein, 1950.) In their calculation, ICE uses a value of river slope for the Delta Colorado gage of 0.000258. (See sheet 2, entitled "All Grains," at line 67 of the Excel file.) The ICE calculations use a river slope approximately 60 percent greater than the actual average reach slope as shown on Table 5 for the Río Sarapiqui to the Caribbean Sea. The correct elevation change for this reach is 8.8 m (3.8 meters plus 5 meters) over a channel length of 52,390 m, or 0.00016. (Even so, the river slope values used by ICE are considerably less than the incorrect value reported by Thorne.) By applying an excessively steep slope, the ICE analysis substantially over-estimates the rate of bedload transport at the Delta Colorado gage. Both ICE and Thorne report that mean annual bedload transport is 2,488,000 tons/year for the years 2011 and 2012 at the Delta Colorado gage. (See Thorne, Table 6.) This is an unusually large proportion of bedload: 29% of the total sediment load at the Delta Colorado gage as calculated by ICE. Typically, bedload makes up less than 10% of total sediment load.

Moreover, the Einstein bedload equation is a poor choice for analysis in this instance; it was formulated based on a model of interaction of flow and particle motion that has been examined in detail and found to be incorrect. (See, e.g. Wiberg and Smith (1989).) I recalculated the bedload transport rates for the Delta Colorado gage using the Fernandez-Luque and van Beek (1976) bedload equation, a river slope of 0.00016, and used all other input hydraulic values as shown in the ICE spreadsheet calculations. Daily values of bedload transport at the Delta Colorado gage from January 1, 2011 to December 31, 2012 were then calculated using the river flows as shown in the ICE spreadsheet. The estimated average annual bedload is approximately 330,000 tons per year, considerably less than the 2,488,000 tons per year calculated using an excessively steep river slope.

As described in detail above at Table 4, river flows – and consequently bedload transport rates – during the years 2011 and 2012 were well below normal. Comparison with gaging station records of 10 years or longer collected by Costa Rica at other sites in the Río San Juan basin indicate that an average magnitude and frequency of river flows would have transported 2.2 times the quantity of suspended sediment carried by actual river flows during 2011 and 2012. Accordingly, the expected bedload transport at the Delta Colorado gage, given the correct river slope, the hydraulic conditions that existed in 2011 and 2012, and normalized for an average magnitude and frequency of river discharges would have been approximately 730,000 tons.

I. Aggradation of Delta Channels

River deltas are an area of sediment accumulation. As the river velocity slackens, the coarser particle sizes will be deposited and accumulate on the river bed. At flood stages, overbank flows will carry finer sediment particles over the adjacent floodplain and wetlands, where they are likely to be deposited. A portion of the river's sediment load will be transported over an extended period of time to the sea. A substantial portion of the sediment will be deposited, eroded, transported, and then re-deposited. Increased river sediment loads, especially the coarser particles, that are transported into the delta area will accelerate the succession of channel filling, migration, and shifting. While these are natural delta processes, an acceleration of these processes can damage the delta ecosystem and create substantial difficulties for human activities and infrastructure. Increased flooding due to the loss of channel capacity, together with the need for more frequent dredging to maintain navigation, are commonly associated with an increased supply of sediment to a delta area.

Thorne relies upon an overly simplified approach when he estimates the effect that sediment eroded from the Route 1856 corridor will have on the rate of river bed aggradation in the Lower Río San Juan.[10] Thorne calculates that the entire increment of sediment eroded from Route 1856 would increase the rate of aggradation by "less than 0.2 mm yr^{-1}." (Thorne, para 8.59.) This value was determined by assuming that the annual increment of additional sediment, 3,650 m^3, would be spread uniformly over a river bed 30 km long and 90 m wide, or 2.7 million m^2. It should be noted that 3650 m^3 of sediment spread over 2.7 million m^2 would be 1.35 mm thick, not less than 0.2 mm as stated (3650/2,700,000 = 0.00135). Thorne recognizes, however, that there was more sediment supplied to the channel than could be transported even before the construction of Route 1856. That is, the Route 1856 sediment will cause an "increase in the rate of aggradation". (Thorne Report, para 8.59.) The additional sediment eroded from the Route 1856 corridor will not be transported downstream and distributed evenly along the channel. This is because the hydraulic characteristics of the channel are insufficient to distribute the excess

[10] The reach of the Rio San Juan from the bifurcation of the Delta Colorado downstream through the delta to the sea will be referred to as the Lower Rio San Juan.

sediment over a length of 30 kilometers. The excess sediment will instead be deposited and aggrade the river bed within a relatively short distance, typically 20 to 30 times the channel width. In the Lower San Juan, this will be the upper 3 km.

The proper approach when determining the rate of river bed aggradation is to consider both the supply of sediment and the rate of sediment transport through the reach. Thorne considers only the supply of sediment, which, as described above, he has underestimated substantially. It is feasible to estimate the quantities of sediment supply and downstream transport at the beginning of the Lower Río San Juan using information provided by Thorne, Costa Rican Annex 4, and the correct river slope. I used a method developed by Engelund and Hansen (1967) to calculate the transport rate of bed-material, i.e. bedload plus suspended sand, assuming river discharges flowing through a channel 90 m wide, with a slope of 0.00016 and a median bed-material size of 0.6 mm. (See Excel spreadsheet attached to Annex 4). My calculation is based on 10 percent of the daily mean discharge reported for the Delta Colorado gage for the years 2011 and 2012, as assumed by Thorne. The result was then normalized to reflect the long-term basin wide runoff. The estimated mean annual transport of bed-material at the beginning of the Lower Río San Juan is approximately 120,000 tons/year or 75,000 m^3/year of relatively coarse sediment.

Poor land-use practices in Costa Rica over recent decades have greatly increased the supply of sediment to the Río San Juan Delta area. As described above, sediment supplied by tributaries to the Río San Juan has increased 20 to 50 times the expected natural rate. Using the estimated mean annual supply of sediment to the head of the delta of about 13.7 million tons of suspended and bedload sediment, as calculated above, the average annual quantity of relatively coarse sediment that will tend to accumulate in the upstream portion of the delta in excess of what would have been deposited when sediment yields were truly natural is approximately 1.0 to 1.5 million m^3.[11] This is a substantial quantity of sediment.

Thorne assumes that 10 percent of the river discharge and suspended sediment load of the Río San Juan flow into the Lower Río San Juan, while the remaining portions flow into the

[11] The quantity of relatively coarse sediment was calculated as bedload plus 7 to 13 percent of the suspended sediment load. The percent of relatively coarse sediment in the suspended sediment load was determined from an analysis of the hydraulic conditions and the bed-material particle size distribution. (See ICE spreadsheet attached to Annex 4). Relatively coarse sediment represents 12 to 18 percent of the total sediment load in the Rio San Juan.

channel of the Delta Colorado. He assumes, however, that only 2.8 percent of the bedload is carried into the Lower Río San Juan. (Thorne, Table 6.) No explanation for the inconsistency is given. As described in detail above, the foundation for these conclusions are highly doubtful. For the purpose of evaluating his conclusion concerning the rate of river bed aggradation in the Lower Río San Juan, however, it will be assumed that 10 percent of the sediment supplied to the head of the delta, approximately 100,000 to 150,000 m^3/year of relatively coarse sediment, is carried into the Lower Río San Juan. The estimated supply of relatively coarse sediment to the Lower Río San Juan is 30 to 100 percent greater than the quantity of sediment that is transported downstream. As described above, this material will accumulate within the first few kilometers of channel. The expected aggradation rate due to an excess of 25,000 to 75,000 m^3 of sediment per year within the first three kilometers of the Lower Río San Juan is in the order of 10 to 30 centimeters per year.

Thorne concluded that the construction of Route 1856 has added about 3,650 m^3 sediment per year to the Lower Río San Juan. It is estimated that between 12 to 18 percent of the total river sediment load is composed of relatively coarse sediment, bedload and suspended sand. Because the upstream portion of Lower Río San Juan is already overloaded and aggrading, 440 to 660 m^3/year of the additional sediment due to the construction of Route 1856, as estimated by Costa Rica, will also be deposited within the first three or so kilometers.

Kondolf has reanalyzed and updated his evaluation of erosion from the Route 1856 corridor. (See Kondolf 2014.) At many sites, the rate of erosion has accelerated and the area affected has expanded. With his updated evaluation, Kondolf estimates that the quantity of sediment delivered to the River annually is between 106,000 and 130,000 m^3 of sediment per year from Route 1856 alone, and between 116,000 and 150,000 m^3 when access roads are considered. Applying the same assumptions, as described above, namely, that 10 percent of the sediment is carried into the Lower Río San Juan and that 12 to 18 percent of the total river sediment load is relatively coarse, 1270 to 2340 m^3 of sediment from Route 1856 alone, and 1390 to 2700 m^3 of sediment from Route 1856 plus access roads will be deposited within the first 3 kilometers of the Lower San Juan.

The average thickness of deposition understates the magnitude of the potential problems, because the accumulating sediment won't be distributed evenly along and across the delta channels. Depending upon such variables as the river discharge, particle size distribution of the sediment loads, ocean tides and channel geometry, the location and rate of sediment deposition will shift up and down stream. (See Carter, 2002.) The accumulating sediment will tend to form bars, which are evident along the delta channels, creating reach-wise instabilities and obstructions to navigation. River bars will grow over time and merge with the river banks in a process known as "accretion." Vegetation will gradually become established on the river bars, which will induce more sediment deposition and the channel will narrow. As the channel fills with sediment, the capacity of the channel will be reduced over time and eventually the flow will find a new course to the ocean. Thus, an increased supply of sediment to the head of the delta will tend to accelerate the rate of filling and abandonment of one channel and the diversion of flow to a new channel.

The finer sediment particles – fine silt and clay, which comprise a majority of the river's sediment – will be transported downstream along the delta channels until the fresh river water begins to mix with tidal surges of ocean water. The resulting mixture is brackish. The presence of salt in the brackish delta waters causes the fine silt and clay particles to flocculate or form larger clumps. The flocculated particles settle more quickly through the water column and are deposited in the channels and adjacent overbank area. The vast majority of the relatively fine sediment will be deposited within the delta and not carried into the ocean as Thorne states.

J. Assessing the Sediment Impacts of Route 1856

Figure 2 is an essential part of Prof. Thorne's analysis concerning the geomorphic effects of Route 1856 on the Río San Juan. It is a copy of Annex 4's Figure 3. It is also shown as Figure 26 in Thorne. The values of suspended sediment concentration and river discharge plotted in this figure are listed in Appendix D of Annex 4. Referring to this figure, Prof. Thorne concludes that "not only is there no statistically significant difference between the pre- and post-Road suspended sediment rating curves, but Figure 26 reveals them to be practically identical." (Thorne Report, para. 8.5.) He later reiterates that "this result demonstrates that the construction of the Road has not led to a significant increase in the SSL [suspended sediment load] carried by the Río San Juan". (Thorne, para. 8.13.)

Figure 2. Copy of Figure 3 and caption from Thorne Report.

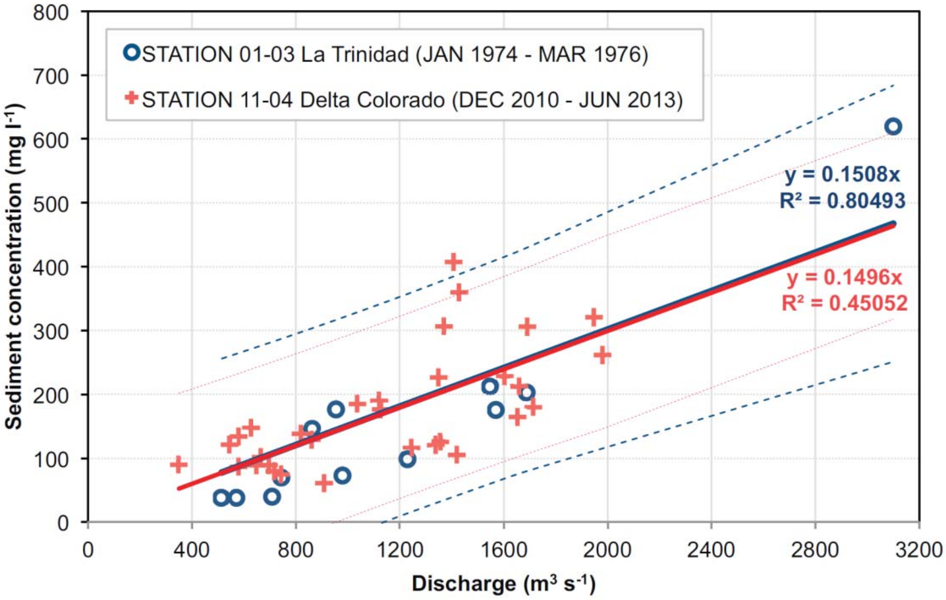
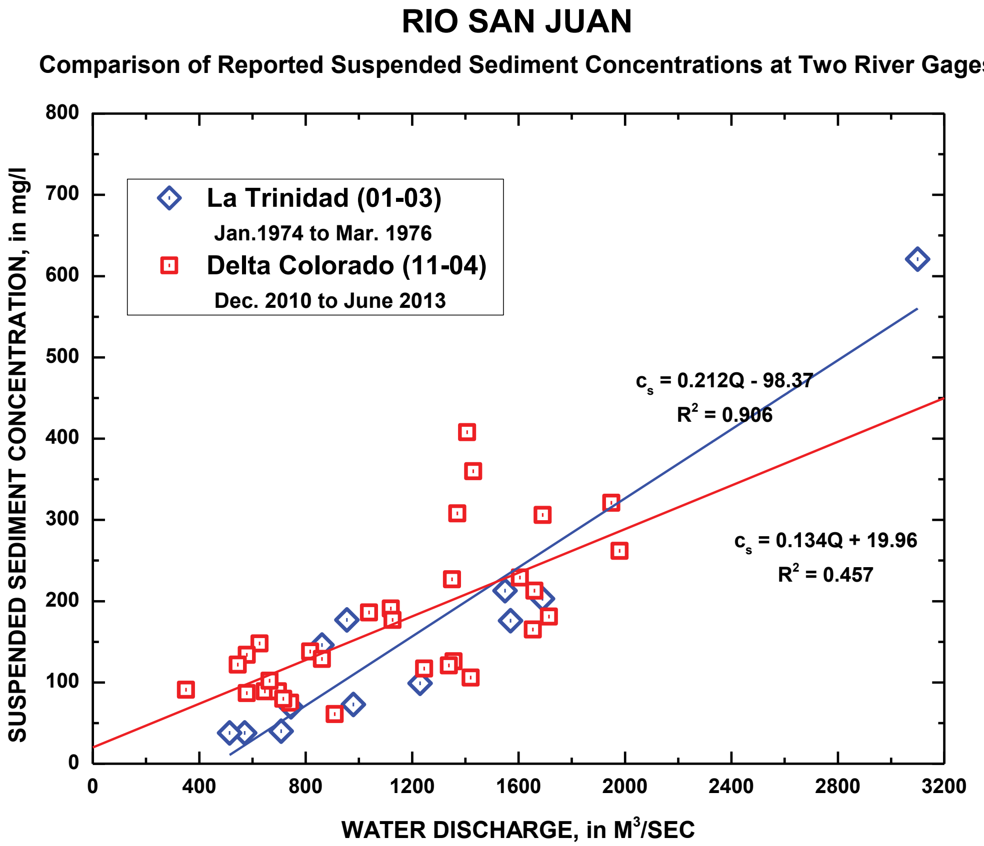


Figure 3. Suspended sediment (SS) rating curves for La Trinidad (01-03) and Delta Colorado (11-04) gauging stations. The two continuous lines represent the regression models fitted to the Discharge – SS Concentration data sets, for both gauging stations. Dotted lines represent the 95% confidence prediction interval of the mean predicted response given by each of the regression models.

The reproduced figure does not support or justify the stated conclusions. Assuming for the time being that the values of suspended sediment concentration listed in Appendix D can be accepted as representative of the actual conditions in the Río San Juan when the samples were collected, the analysis shown in the reproduced figure is invalid. The two lines shown in Figure 2 were determined – i.e. fitted to the reported values – by the method of least-squares regression with an additional condition that the fitted lines must pass through the graph origin point located at (0, 0). This additional condition violates the assumptions relied upon to derive the method of least squares regression. By imposing the condition that the two lines intersect at the origin, the analysis makes the two trend lines appear to be nearly identical, when, in fact, they are different. The result is invalid and creates a misleading impression.

In Figure 3, I have recalculated the trend lines, using the same values of suspended sediment concentration and river discharge shown in the reproduced Thorne Figure 2. Trend lines have been fit to the values for the two river gages using the same method of least-squares regression, but without requiring that the trend lines pass through the 0-0 origin point. This statistically proper analysis reveals that suspended sediment concentrations sampled at the La Trinidad gage from 1974 to 1976 and the Delta Colorado gage from 2010 to 2013 are not the same.

Figure 3. Comparison of reported suspended sediment concentrations as a function of river discharge for the Río San Juan La Trinidad gage (01-03) and the Río Colorado Delta Colorado gage (11-04).



A standard statistical method known as the t-test can be applied to determine whether the slopes and intercepts of the two fitted trend lines are statistically different.[12] The slopes and intercepts of the trend lines shown in Figure 3 are statistically different at the 95% level of

[12] The test for "statistically different" calculates the probability or level of confidence that the two sets of data come from different populations. A t-test significant at the 95% confidence level means that 95 out of 100 times the two sets of data come from different populations. A t-test significant at the 99% level of confidence means that 99 out of 100 times the two sets of values come from different populations.

confidence. This result shows that one can confidently conclude that suspended sediment concentrations at the La Trinidad gage from 1974 to 1976 were not the same as suspended sediment concentrations at the Delta Colorado gage from 2010 to 2013. Thus, Thorne's conclusion that the construction of Route 1856 has not led to a significant increase in the suspended sediment load is not supported by the data.

There is another significant problem with the analysis and presentation shown in Figure 3 of the Thorne report – Thorne has assumed a linear equation for the relation between suspended sediment concentrations and water discharge. The assumption of a linear equation is inconsistent with the approach applied by ICE in its analysis of sediment records as reported in Annex 4, Figure 4. It is also inconsistent with common practices for suspended sediment analysis worldwide.

More specifically, the method of least-squares regression applied to derive the results shown in Thorne Figure 3 requires an assumption concerning the variation of suspended sediment concentrations, Cs, with river discharge, Q. The investigator must select the appropriate fundamental governing equation. The results shown in Thorne Figure 3 were determined by imposing a linear equation:

$$C_s = aQ + b$$

where "a" and "b" are constants determined by the least-square regression. (As described above, Thorne set the constant "b" to be equal to zero for the analysis shown in his Figure 3.) The equation states that the suspended sediment concentration of a given river discharge can be determined by multiplying the river discharge, Q, by a constant, a, and then adding a second constant, b. The choice or assumption of a linear relation between suspended sediment concentration and river discharge is highly unusual. Except in extraordinary circumstances, where there is compelling evidence to do otherwise, hydrologists have found that a power function (or power equation) is the most appropriate governing equation to describe the variation of suspended sediment concentrations with river discharge. The general form of the power function is:

$$C_s = aQ^b$$

where "a" and "b" are constants determined by the least-squares regression.

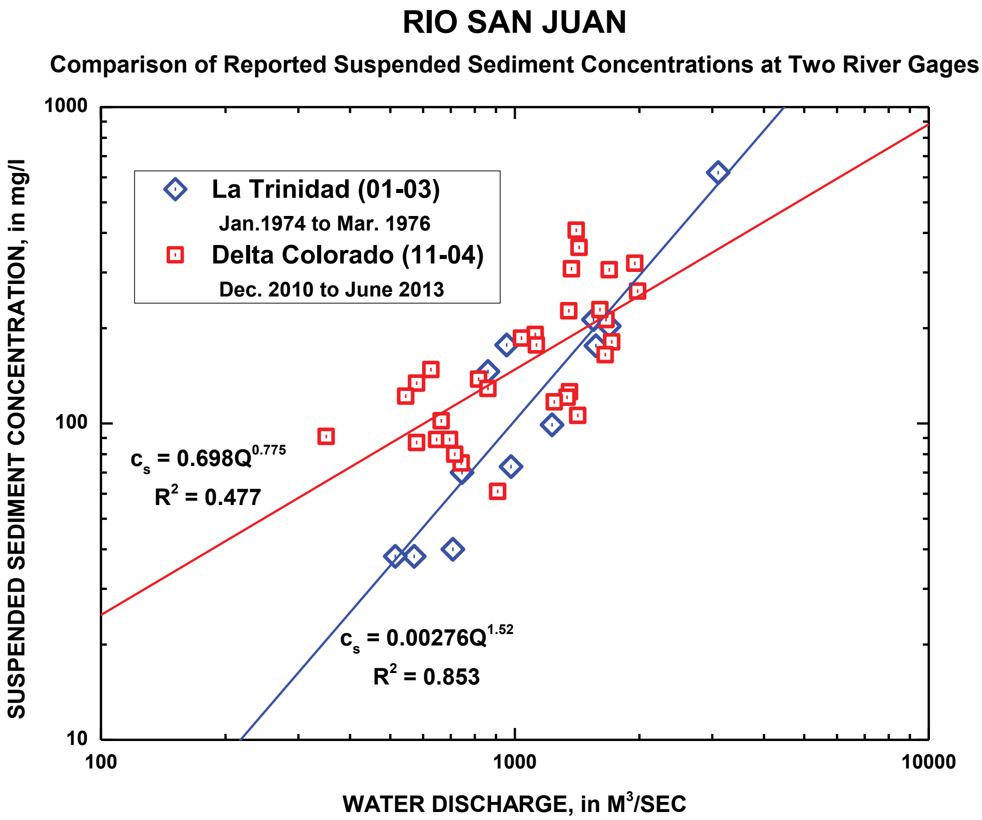
In fact, Thorne's failure to use a power function is inconsistent with the characterization of suspended sediment transport presented by ICE in Annex 4. ICE uses a power function to fit the observations of suspended sediment concentration and river discharge at the 12 Río San Juan tributary gages summarized in Annex 4, Appendix A, pages 181-205. Among all the gage records where the relation between suspended sediment concentration and water discharge were determined, only two – La Trinidad and Delta Colorado – assumed a linear function. For the other 12 gage records, ICE applied a power function.

The relations shown in Figure 3 only appear to be similar because the values are fit to a linear equation that was forced to pass through the origin. Because only a small number of sediment samples were collected over a limited range of river discharges at the La Trinidad and Delta Colorado gaging stations, the figure gives the impression that the linear equation might be an appropriate model. With a larger number of samples, the inappropriate choice of the linear equation would be more apparent.

In Figure 4, I have recalculated the trend lines assuming a power function for the same reported values of suspended sediment concentrations and river discharges for the La Trinidad and Delta Colorado gages shown at Annex 4 Appendix C. The new trend lines are calculated by the least-squares regression method. The figure axes have a logarithmic scale, rather than the linear scale shown in Thorne's Figures 2 and 3. The fitted relations shown in Figure 4 were determined using the same or essentially the same method as applied by Costa Rica to the 12 tributary gages listed in Table 3.

As explained above, I employed a t-test to determine the statistical significance of the two equations shown in Figure 4. The t-test determines the likelihood that the two equations are, in fact, different. The t-test demonstrates that the suspended sediment concentrations sampled at the La Trinidad gage from 1974 to 1976 are different from those sampled at the Delta Colorado gage from 2010 to 2013. The t-test revealed that the slope and intercept, i.e. the constants "a" and "b" as determined for the two sets of values, are statistically different at the 99 percentile level of confidence. That is, there is only one chance in 100 that the observed suspended sediment concentrations at La Trinidad in 1974 to 1975 are the same as the concentrations that were observed at the Delta Colorado in 2011 to 2012. Prof. Thorne's conclusion that the suspended sediment concentrations in the Río San Juan Basin have not changed over the past forty years is demonstrably false.

Figure 4. Variation of suspended sediment concentration as a function of river discharge for the La Trinidad (01-03) and Delta Colorado (11-04), assuming a power relation.



Moreover, the change in line slopes over the nearly forty year period shown in Figure 4 is consistent with the expected increase in sediment loads associated with the extensive deforestation that has occurred. The rate of change in suspended sediment concentration for a given change in river discharge appears to have decreased between the 1974 to 1976 period at the La Trinidad gage and the 2010 to 2013 period at the Delta Colorado gage. That is, the relation for the Delta Colorado gage is flatter. Such a change over time is commonly observed where the particle size of suspended sediment decreases, i.e. the suspended sediment consists of relatively more clay, silt and fine sand and lesser amounts of medium to coarse sand. (See

Andrews, 1987.) The particle size distributions of suspended sediment samples collected at the La Trinidad and Delta Colorado gages were not reported in any of the Costa Rican documents, so this explanation cannot be verified. Nevertheless, the reported values could indicate both a change in suspended sediment concentrations and a decrease in particle size, both of would be consistent with accelerated landscape erosion.

K. Improper Sampling of Suspended Sediment

There is compelling evidence to question the validity of some and perhaps all of the suspended sediment samples collected at the Delta Colorado gage. The concentration of suspended sediment must be determined by collecting a discharge-weighted sample of the river discharge. For a river channel as wide as at the Delta Colorado gage, samples will typically be collected at 20 to 30 verticals spaced out across the channel. Typically, one and one-half to two hours will be required to collect a representative sample of suspended sediment at a channel as wide as exists near the Delta Colorado gage.

The values of suspended sediment concentration and river discharge reported for the Delta Colorado gage are listed in Annex 4, Appendix C, together with the date and time of day on which the sample was taken. There are three dates – March 2, 2011, March 3, 2011, and January 30, 2013 – when two samples of suspended sediment were collected on a given day. On March 2, 2011, the samples were collected nine minutes apart. On March 3, 2011, the samples were collected four minutes apart. On January 30, 2013, the samples were collected five minutes apart. It is physically impossible to collect a representative sample of suspended sediment from a river cross-section that is several hundred meters wide in just a few minutes. The samples collected on these dates therefore cannot be relied upon. Costa Rica does not provide any information in its documents concerning the methods and equipment used to collect the reported suspended sediment samples. Nevertheless, both the ICE and Thorne reports treat the reported values as though they are representative samples of conditions extant on the river when the samples were collected. For the three dates described above, this cannot be true. One suspects that the reported concentrations were determined from either a bucket full of surface water or, perhaps, a depth-integrated collected at a single vertical. Neither of these methods will provide a representative sample with which one can determine the amount of suspended sediment in the river. In the absence of evidence to the contrary, all of the reported values of suspended sediment collected at the Delta Colorado gage are suspect.

VI. ECOLOGICAL IMPACTS OF EXCESSIVE SEDIMENT SUPPLY TO THE COASTAL ZONE

For purposes of this report, the consideration of sediment impacts within the coastal zone of Nicaragua due to accelerated erosion in the Río San Juan Basin must be relatively general. Locally focused studies are almost entirely lacking. The general principles, however, have been well-studied and are widely recognized. Excessive rates of sediment deposition will impair and can substantially alter the structure and function of a coastal ecosystem. Coastal ecosystems are typically highly productive and diverse. This is especially true of the Caribbean coast of Central America. Today, coastal ecosystems worldwide are frequently impaired by excessive sedimentation. (See Thrush and others, 2004.) The following discussion will provide three examples of important coastal ecosystems, each of which is commonly affected by accelerated sedimentation: estuarine benthic populations, mangrove forests, and coral reefs.

Thrush and others (2004) reviewed the available scientific literature on the effects of sedimentation in estuarine and coastal benthic ecosystems. As little as 3mm of freshly deposited sediment is sufficient to impair ecosystem structure and function. Thrush and his colleagues found that as little as 2 centimeters of sediment was enough to smother and kill a wide variety of organisms, such as bivalves, snails, worms, and crustaceans. This finding, if applied to the Río San Juan basin, suggests that significant biological impact can be expected from the addition of sediment load. The Río San Juan carries the sediments eroded from its watershed to the coastal zone, and as described above, a majority, perhaps 50-70%, of the mean annual suspended sediment of about 13 million tons per year – or 6.6 to 9.2 million tons per year – consists of clay and fine silt. In the upstream portions of the river, these very small particles tend to remain suspended in the flow. When the river water begins to mix with the brackish estuarine water, however, the particles of clay and fine silt will flocculate. The aggregated clumps of clay and silt are no longer easily suspended and will tend to settle to the bottom. The coastal zone is an environment formed by the transport, deposition, and re-entrainment of sediment. (See Carter, 2002). Depending on the strength of the waning river current, tides, waves, and near-shore ocean current, flocculated particles of the fine sediments will be distributed to a complex of geomorphic features, i.e. into the distributary channels through the delta, or into adjacent wetlands, estuaries, lagoons, beaches in the near-shore zone, and coral reefs. The plants, animals, and micro-organisms living in the coastal zone have adapted to an environment where fine sediment particles are deposited, re-suspended, and then deposited again. As Thrush and his colleagues demonstrated however, depending on the particular organism, there are limits to the sediment thickness that can accumulate in the environment without causing the organism substantial harm and death.

Similarly, estuaries along the Caribbean coast of Nicaragua and Costa Rica contain stands of mangrove as well as other plants adapted to living in water. (See Spalding and others, 1997.) Because these plants are typically rooted in an anaerobic substrate, they have commonly evolved aerial roots. The deposition of an excessive thickness of sediment can smother these roots and suppress or prevent necessary respiration. Increased rates of sedimentation have been identified as one of the primary threats to mangrove ecosystems worldwide. (See Alongi, 2002; McLaughlin and others, 2003.) Ellison (1998) compiled reported rates of sediment deposition in mangrove forests. Ellison considered 26 different studies of mangrove and related vegetation impacted by increased sedimentation, and found that some species are more successful in adapting to sedimentation than others. Short-term rates of sediment accretion in the range of 0.5 to 5 mm per year were observed in mangrove forests without noticeable negative impacts. Other species have survived sediment accumulations of nearly 100 centimeters. On the other hand, sediment accumulations of as little as 10 centimeters have been observed to create unhealthy conditions and, for some species, cause death.

Coral reefs throughout the Caribbean have been negatively impacted by large increases in the quantity of sediment eroded from the land surface and transported to the ocean. Elevated rates of sediment deposition directly onto the coral formation as well as increased turbidity have been associated with slower growth rates, changes in coral species, and reduced overall ecosystem productivity. (See, e.g. Rogers, 1990.) Cortes and Risk (1985) described an investigation of the Cahuita reef off the Caribbean coast of Costa Rica which found the reef had been impaired by excessive rates of sedimentation. They concluded that forest clearing and conversion of land to agricultural uses was the most likely cause of increased reef sediment. Although the Cahuita reef is south of the Río San Juan delta, rivers draining the adjacent coastal plain from the Río San Juan south through Costa Rica have been similarly affected by extensive deforestation and, one would expect, now supply much greater quantities of sediment to the coastal zone.

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ANNEX 4

Dr. Blanca Ríos Touma, "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua", July 2014

Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua

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1. Introduction

A. Effects of Sediment on River Biota

Human caused sediment releases (*e.g.* from road construction, mining and agriculture) can induce changes to the physical habitat and aquatic biota downstream from the sediment source (*e.g.* Fossati et al. 2001; Spelleberg 1998). These effects have been well documented in temperate rivers and have been summarized in scientific publications, such as Wood and Armitage (1997). Effects on habitat modification include changes in substrate, from bigger and more stable substrates to smaller and more unstable substrates. Increased suspended sediment concentrations and turbidity impairs the respiration ability of some invertebrates and fish.

Increased sedimentation has impacts on primary producers (periphyton and macrophytes) in streams and rivers, which constitute the base of the food chain, such that deleterious impacts will also be manifested in the invertebrate and fish communities (Wood and Armitage 1997). Increased fine sediments affect primary producers in four ways: (1) reducing light penetration with a resulting reduction in photosynthesis and primary productivity (Van Nieuwenhuyse and LaPerriere 1986); (2) reducing the organic content of periphyton cells (Cline et al. 1982, Graham 1990); (3) damaging macrophytes due to abrasion (Lewis 1973a,b); and (4) preventing attachment to substrate and removing periphyton and aquatic macrophytes in extreme events (Brookes 1986).

While stream biota is generally adapted to changes in flow and sediments, when sediment inputs are artificially elevated, the effects on aquatic biota can be severe. Abnormal sediment loads can reduce benthic invertebrate communities, with 47% reduction in benthic invertebrates documented on the West Coast of the South Island in New Zealand due to elevated sediments from mining (Quinn et al. 1992). These reductions can be attributed to drift due to unstable substrate (Culp et al. 1995), reduction of suitable habitat for some species (Richards and Bacon 1994), reduction of respiration due to silt deposition on breathing structures or oxygen reduction (Lemly, 1982), changes in food availability (Cline et al. 1982, Peckarsky 1984 Graham 1990) and overall changes in the river foodweb (Henley et al., 2000).

These ecosystem changes due to sediments have profound effects on ecosystem function by affecting specific macroinvertebrate traits, thus affecting their functions on the ecosystem. For example Richards et al. (1997) found that increased fine sediment loads significantly affected macroinvertebrates of long-lived forms, scrapping feeding habits and clingers, showing that specific macroinvertebrate traits were especially affected by high sediment loads.

B. Rte 1856 Along the Rio San Juan

Rte 1856 extends in Costa Rica along most of the south bank of the Rio San Juan. The road is close to the river bank, nearly half within 100 m of the river bank. Sediments eroded from the road are carried into the Rio San Juan at discrete point sources, in larger natural drainages to which the road drains, or by new, smaller gully systems that drain eroding sections of the road. Road-derived sediments either deposit on natural deltas, or in some cases have built up new deltas that are not naturally there.

We documented ecological communities on gravels in deltas of tributary streams, comparing conditions on deltas of streams draining mostly undisturbed forest on the north bank (Nicaragua) with deltas affected by road-derived sediment along the south bank (Costa Rica). These deltas contain gravel substrate in shallow water, suitable for colonization by macroinvertebrates and periphyton (the algae growing on pebbles and cobbles). The deltas extend from the river bank out into the channel. Differences in the benthic communities sampled on the two banks of the river should reflect effects of the elevated sediment loads coming from erosion of Rte 1856.

Benthic organisms are indicators of ecosystem health. Since they live on the benthos of the streams and rivers, their composition, richness and abundance reflect the recent history of the river, providing information regarding its impairment. Sampling these insects is affordable and produces reliable information about water quality (Resh, 2008). For these reasons, macroinvertebrates are used worldwide in stream and river bio-monitoring programs (Bonada et al, 2006; Resh, 2008). Benthic invertebrates and algae are among the required indicators to establish the ecological quality according to the European Water Framework Directive (D.O.C.E, 2000). Costa Rican law also requires sampling and analysis of macroinvertebrates as a basis to evaluate and classify surface water quality (MINAE-S, 2007).

2. Methods

We selected 16 sites suitable for sampling of benthic indicators: Deltas of eight creeks located along the north bank of the Río San Juan (draining undisturbed forest in Nicaragua, sites marked as B) and deltas of eight creeks along the south bank, draining Rte 1856 in Costa Rica (sites marked as A) (Table 1, Figure 1). Most sites corresponded to small drainage sizes (Table 1), with the exception of sites 1B, 4B, 4A, and 9A that are larger. Sampling was conducted three times during spring 2014: at the end of March, mid-April, and early May. At each sample site, we collected benthic periphyton and macroinvertebrate samples. In addition to these 16 sample sites, we took one sample for periphyton (with 3 replicates) and one for macroinvertebrates on a newly disturbed delta draining the road at "la Chorrera" (point 9A) on the early May sampling trip.

To characterize the sites, we measured temperature, pH and conductivity with field probes. We also conducted pebble counts following Kondolf (1997) to characterize grain size of the sites.

We sampled the periphyton biomass at each river delta on similar substrate (pebbles and cobbles) according to Steinman et al. (2006), scraping a fixed 4x4 cm area of 3 different pebbles or cobbles then filtered in a Whatman® glass microfiber circle filter, Grade GF/F (47 mm). The filter was stored on a glass container covered by aluminum paper and stored at 4 ºC when in transport (maximum 4 hours) and then stored at -20 ºC until the analysis in the lab. The analysis included the extraction in 15 ml of 90% buffered acetone for 24 hours in the dark, centrifugation and then measurements of Chlorophyll *a* in a spectrophotometer. Living algae contain mainly undegraded Chlorophyll, but with algal senescence or death, detritus degradation products also appear in the samples, mainly pheophytin (Stienman et al. 2006). Because pheophytin absorbs light in the same spectrum of Chlorophyll *a*, measurements have to be corrected by acidifying the samples (with 0.1 mL of 0.1N HCL for 3 minutes), making measurements before and after the acidification.

Turbidity and colored materials can interfere with Chlorophyll *a* measurements (Stienman et al. 2006). In order to correct the Chlorphyll *a* values due to turbidity and colored materials we subtracted the absorption readings at 750 nm of those at 664 nm. For the pheophytin correction, after acidifying the sample, we measured at 665 nm and at 750 nm (for turbidity correction purposes).

We used the formula:

$$\text{Chlorophyll } a\ (\mu g/cm^2) = 26.7\ (E_{664b} - E_{665a}) \times V_{ext} / \text{area of substrate } (cm^2) \times L$$

Where:

E664b= (Absorbance of sample at 664nm) − (Absorbance of sample at 750nm) before acidification;

E665a = (Absorbance of sample at 665nm) − (Absorbance of sample at 750nm) after acidification;

V_{ext}=Volume of 90% acetone used in the extraction (mL), in our case 15 ml;

L=length of path light through cuvette (cm), in our case 1 cm;

26.7= absorbance correction (derived from absorbance coefficient for chlorophyll a at 664nm x correction for acidification).

These analyses were performed at the laboratory of Empresa Nicaraguense de Acueductos y Alcantarillados Sanitarios (ENACAL) in Managua, following the Standard Methods 10200H(2) (APHA 1998, 20th).

Macroinvertebrates were sampled with a D-net of 500 microns mesh (Standard Methods 10500 (APHA 2006, Online Edition, Hauer & Resh 2006). We took one sample per delta, collecting from as many shallow gravel-bedded areas as was possible during a 2-minute sampling period. Samples were fixed in the field with alcohol 90º. These samples were analyzed in laboratory by Dr. Raúl Acosta, an expert on Latin-American macroinvertebrate taxonomy, to the lowest taxonomical level possible (at least family level for insects). To assess functional differences of the macroinvertebrate community among deltas, we classified the invertebrates found according to their feeding modes or functional feeding groups, following Ramirez & Gutierrez (2014), Dominguez & Fernandez (2009) and Merrit et al. (2008).

For each site, we calculated taxonomical richness and abundance. Also, as a metric of biological quality, we calculated the richness and abundance of Ephemeroptera, Plecoptera and Trichoptera (EPT). This is a highly used metric in biomonitoring of streams and rivers (Chang et al. 2014; Carter and Resh, 2013).

Statistical Analysis

To characterize substrate we calculate the d16, d50 and d84 statistics, which are respectively the sizes at which 16, 50 and 84% of the sampled sediments are smaller. The d50 is the median size, i.e., half of the grains in the sample were larger, half smaller; it is a commonly used indicator of central tendency of the size distribution. Sorting refers to the extent to which the sediments are of similar size, and reflects the processes of selective transport and deposition of sediments by river flows. Sediments that have been subject to fluvial transport for a longer period tend to be better sorted than sediment recently derived from erosion of bedrock, which tend to have a wider range of grain sizes present. To assess how well sorted the gravels were, we calculated the geometric sorting coefficient (Otto 1939, Inman 1952) as $sg = (d84/d16)^{½}$, where the smaller the coefficient, the better sorted the sediment. To compare environmental variables between deltas draining the road and deltas of creeks draining forest we used the Median test (Chi square).

To analyze differences in periphyton biomass and macroinvertebrate metrics between deltas draining the road and deltas of creeks draining forest, we used Kruskal-Wallis Analysis of Variance, suitable for non-parametric data. We also performed a Non-Metric Multidimentional Scaling fitting the environmental and substrate size statistics as vectors to assess differences in composition of the macroinvertebrate community.

Table 1. Location of sampled deltas in the San Juan River, Nicaragua. "A" points correspond to deltas formed by creeks draining the road at the south bank of the river and "B" points correspond to deltas formed by draining the Nicaraguan side at the north bank of the river.

Point	LONG	LAT	APPROXIMATE DRAINAGE AREA (Km^2)*
1A	-84.35933333300	10.99698500000	1.5
1B	-84.29281034980	10.91394448280	>25
2A	-84.28382000000	10.89443000000	0.25
2B	-84.28700359230	10.90482145620	1.5
3A	-84.28213166700	10.89327333300	0.1
3B	-84.26302965570	10.89231645490	0.4
4A	-84.26815310670	10.89182263050	6.8
4B	-84.28559759790	10.90077234720	> 10
5A	-84.35409933930	10.99030940540	1
5B	-84.21508833300	10.84640666700	0.4
6A	-84.27846253600	10.89264772500	0.4
6B	-84.21835833300	10.86338000000	0.7
7A	-84.27767348230	10.89269348540	0.2
7B	-84.23483789070	10.87701472010	0.4
8A	-84.26354020910	10.89096424330	0.5
8B	-84.24867105280	10.88897071090	1.6
9A	-84.23740666700	10.87652500000	4.8

*Calculated from available topographic maps.

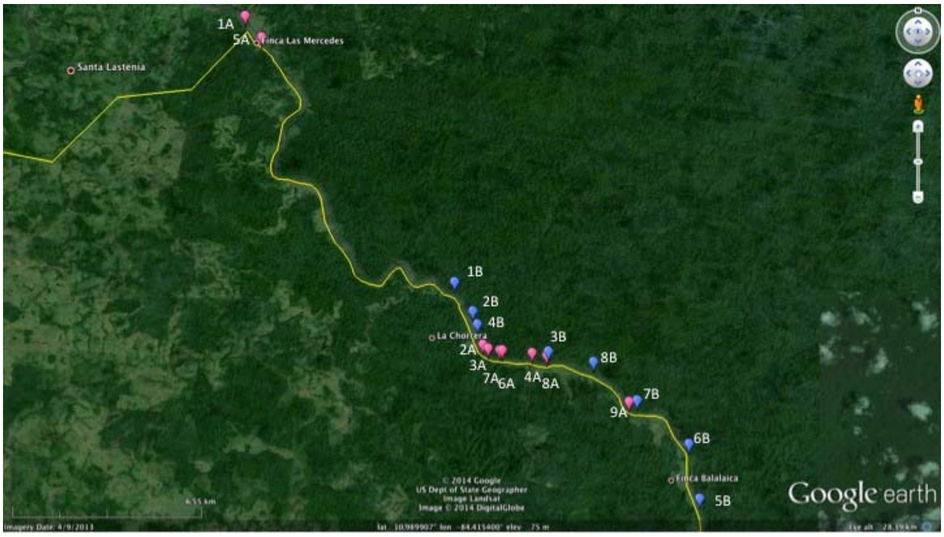

Figure 1. Sampling Points along the San Juan River between El Castillo and Boca del Río San Carlos. Each point corresponds to one delta formed by a creek draining to Río San Juan.

3. Results

A. Substrate and environmental variables

Temperature was significantly higher at deltas of the south bank (27.7 °C, Chi-Square=9.0, df=1, p=0.0027) compared to the north bank (25.83 °C). This difference is most likely attributable to effects of solar heating on deforested lands along the south bank contrasted to the forested areas on the north bank. The substrate statistics d16 and d84 were also different among deltas on the north bank compared to the south bank. D16 (Chi-Square= 6.35, df=1, p=0.0117) was higher (bigger substrate) in the north bank compared to the south bank (9.6 vs 7.5) and d84 (Chi-Square= 4, df=1, p=0.0455) was smaller in the north bank compared to the south Bank (28.75 vs 37). Although mean conductivity and sg (sediment sorting coefficient) were higher at the south bank, no significant differences were found (Appendix 1).

B. Periphyton

The three sampling events at 16 sites yielded a total of 143 samples. We had to eliminate 6 samples draining the road due to excess of turbidity (750 nm readings higher than 664 and 665 nm readings). We eliminated 2 samples from the south bank draining the road and one from the north bank for pheophytin measures exceeding the Chlorophyll *a* measurements, meaning that the periphyton was not alive in those samples. After this first round of elimination, we had 63 samples from deltas along the south bank and 73 from deltas along the north bank.

Our results (Figure 2, Table 2) show highly significant differences between the north and south-bank deltas. Deltas affected by road-derived sediment (south bank) showed significantly lower periphyton biomass values (KW-H $_{(1,135)}$ = 13. 13, p = 0.0003).

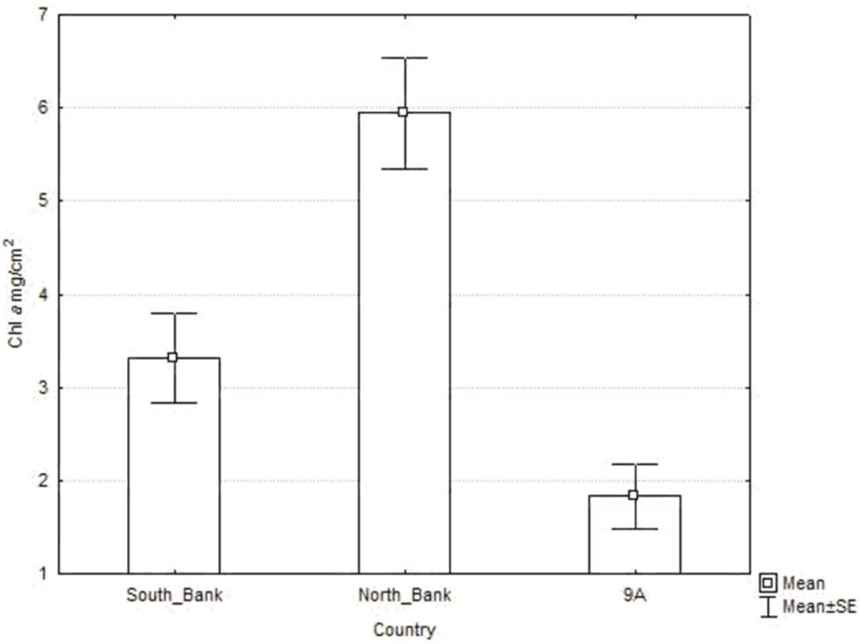

Figure 2. Periphyton biomass on benthic substrate (pebbles and cobbles) in deltas along the south bank of the Rio San Juan (receiving sediments eroded from Rte 1856), along the north bank (formed by streams draining forest), and at Point 9A (La Chorrera).

Table 2. Mean, minimum and maximum values of Cholorphyll a (mg/cm2) at each site.

Site	Mean	Minimum	Maximum
1A	1.75	0.10	3.40
2A	2.29	0.10	5.41
3A	1.81	0.20	5.11
4A	3.18	0.10	5.51
5A	8.92	4.61	20.73
6A	0.77	0.10	2.00
7A	1.72	0.20	4.61
8A	4.68	0.20	12.62
9A	1.84	1.20	2.40
1B	5.02	3.20	9.51
2B	7.62	0.40	18.32
3B	3.98	0.20	18.82
4B	3.14	0.50	10.21
5B	6.01	0.80	16.92
6B	8.17	2.80	14.12
7B	6.95	0.40	17.32
8B	6.59	0.70	20.03

Samples from the site at La Chorrera (9A, Figure 2) had a lower mean than those reported for the other road drainages (1.8 µg/cm^2, outside the lower limit of the standard error range).

C. Macroinvertebrates

We found 54 groups of macroinvertebrates at the deltas of San Juan River (Appendix 2). Macroinvertebrate richness (Table 3, Figure 3) and abundance (Figure 4) was significantly higher in the northern bank compared to the south bank. Groups more sensitive to environmental changes, EPT (Ephemeroptera, Plecoptera and Trichoptera), had higher richness and abundance at the North Bank compared to the south bank, although not in a significant fashion (Figure 5 and 6).

Site 9A, sampled twice, had very low richness (average of 2.5 taxa/sample) with less taxa than the mean for the South Bank. Also, abundance was lower than the mean for sites at the Southern bank (average of 8.5 individuals/sample). Non EPT taxa were found on this site and *Melanoides tuberculata*, an invasive species of snail, was found on both occasions on this site (Appendix 2).

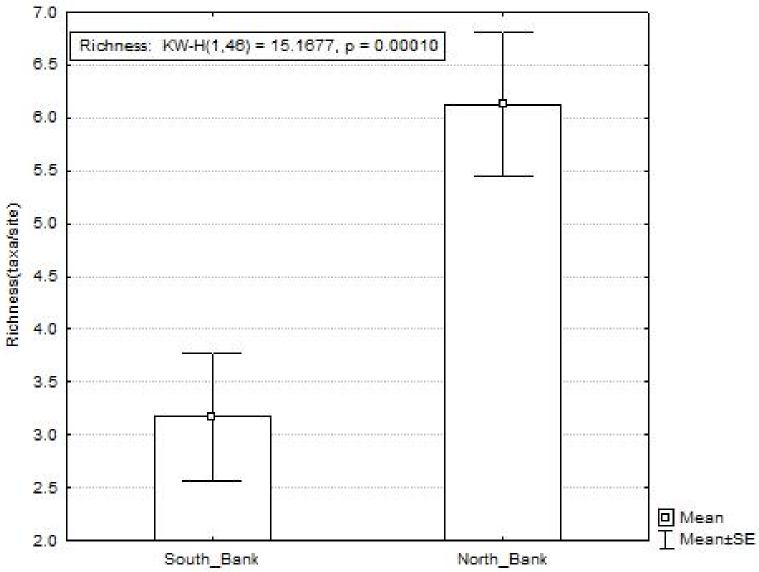

Figure 3. Differences in benthic macroinvertebrate richness among deltas on the north bank and the south bank of the San Juan River**.**

Table 3. Macroinvertebrate richness and abundance as well as richness and abundance of EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa on deltas sampled at the south (A) and north (B) Banks of the San Juan River, Nicaragua. Av.= Average; S.E.= Standard Error of the Mean; min-max= minimum and maximum values found.

Site	Richness (Av.)	S.E. Richness	Richness (min-max)	Abundance (Av.)	S.E. Abundance	Abundance (min-max)	EPT Richness (Av.)	S.E. EPT Richness	EPT Richness (min-max)	EPT Abundance (Av.)	S.E. EPT Abundance	EPT Abundance (min-max)
1A	1.7	0.3	1-2	2.7	0.7	2-4	0	0	0	0	0	0
1B	7.3	2.6	3-12	68.0	40.4	11-146	0.7	0.3	0-1	1.3	0.7	0-2
2A	2.3	0.3	2-3	5.7	3.2	2-12	0.3	0.3	0-1	0.7	0.7	0-2
2B	9.0	3.6	4-16	24.3	5.8	15-35	3.3	1.9	1-7	9.7	6.7	2-23
3A	3.0	0.6	2-4	6.0	3.5	2-13	0.7	0.7	0-2	1.0	1.0	0-3
3B	3.0	0.0	3-3	9.5	2.5	7-12	0	0	0	0	0	0
4A	5.3	2.3	3-10	15.3	10.9	3-37	1.7	0.9	0-3	2.7	1.8	0-6
4B	6.0	0.6	5-7	99.3	52.0	10-190	1.3	0.9	0-3	1.7	0.9	0-3
5A	8.3	1.8	5-11	32.7	4.3	27-41	1.7	0.7	1-3	4.3	2.3	2-9
5B	5.3	1.2	3-7	78.3	51.5	20-181	0.3	0.3	0-1	0.7	0.7	0-2
6A	2.0	0.0	2-2	5.0	0.6	4-6	0	0	0	0	0	0
6B	8.0	1.7	5-11	30.3	12.5	15-55	2.3	0.7	1-3	8.7	3.9	1-14
7A	1.0	0.0	1-1	3.5	2.5	1-6	0	0	0	0	0	0
7B	5.3	1.2	3-7	16.7	6.2	5-26	0.3	0.3	0-1	0.7	0.7	0-2
8A	1.3	0.3	1-2	3.0	1.0	1-4	0	0	0	0	0	0
8B	4.0	0.6	3-5	6.7	1.2	5-9	0.7	0.7	0-2	0.7	0.7	0-2

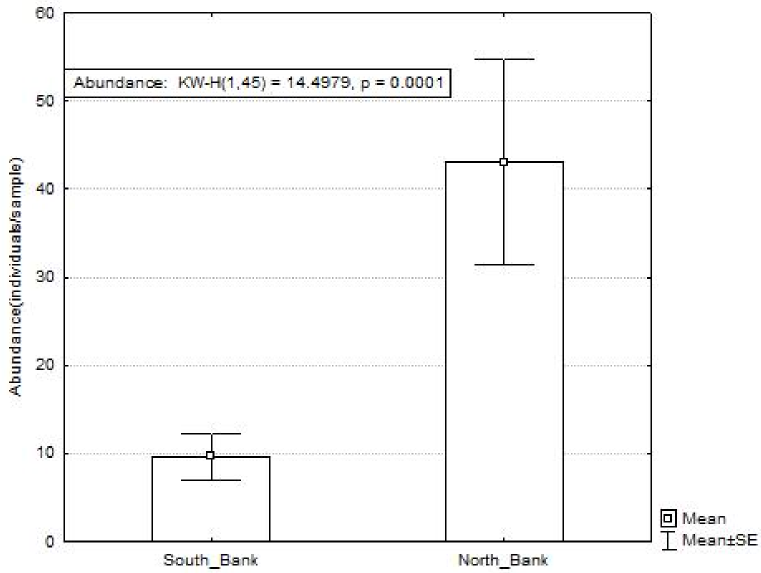

Figure 4. Differences in benthic macroinvertebrate abundance among deltas on the north bank and the south bank of the San Juan River.

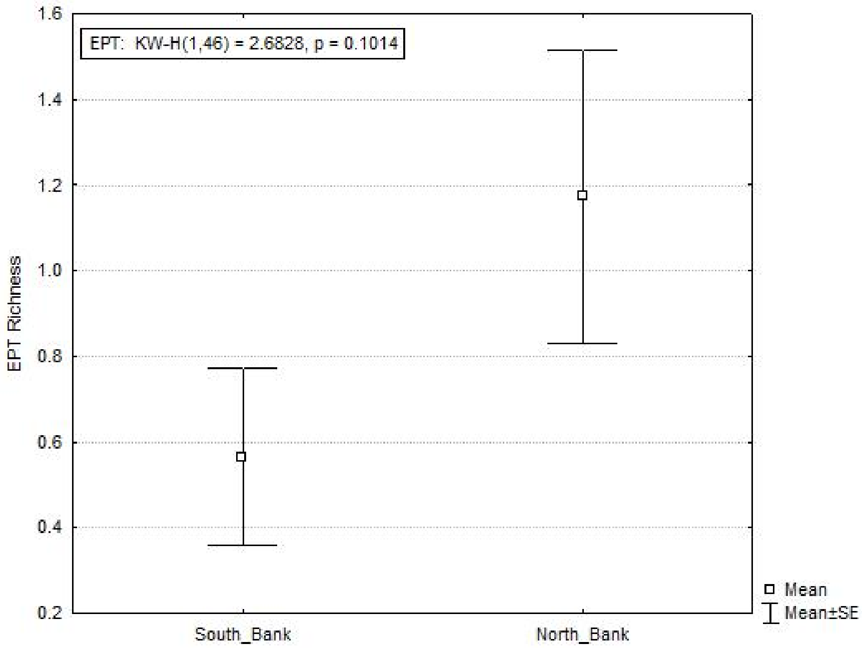

Figure 5. Differences in EPT (Ephemeroptera, Plecoptera and Trichoptera) richness among deltas on the north and south bank of the San Juan River.

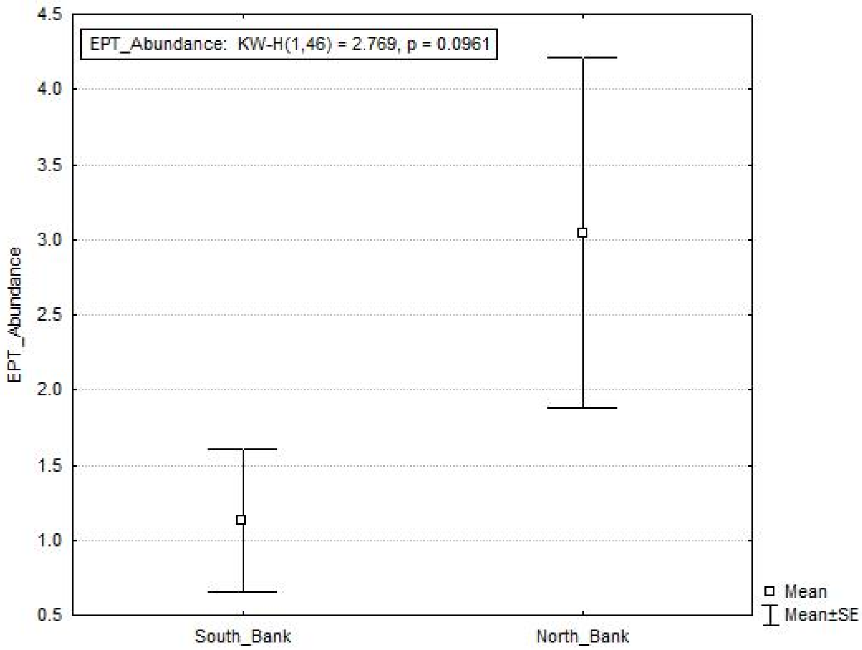

Figure 6. Differences in EPT (Ephemeroptera, Plecoptera and Trichoptera) Abundance among deltas on the north and south bank of the San Juan River**.**

D. Composition Changes

The non-metric multidimentional scaling analysis (Figure 7) showed a segregation of most sites of the north and south bank across axis 2. This axis had negative a relationship (Table 4) with d16, d50 and pH. On the other hand this axis had positive relations with Temperature, sediment sorting coefficient (sg) and d84, therefore showing that most sites on the South bank macroinvertebrate composition were influenced by smaller d16, d50, bigger d84 and higher sg and temperature. The only exceptions were the sites 5A (South Bank) that clustered in the opposite bank (Figure 7). On the other hand the macroinvertebrate communities were influenced by bigger d16, d50, lower temperatures and better-sorted sediments (lower sg coefficient).

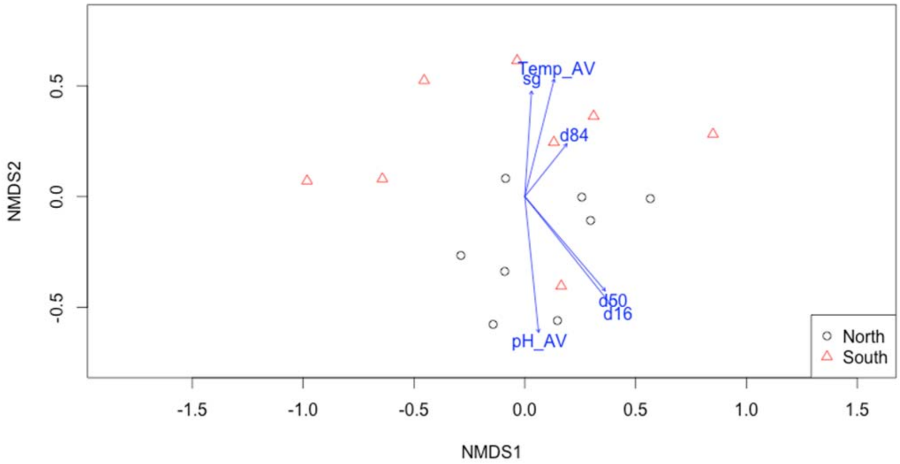

Figure 7. No-Metric-Multidimentional Scaling (NMDS) of macroinvertebrate assemblages at deltas of the north (Circles) and south (Triangles) of the San Juan River, Nicaragua. Vectors represent the substrate and environmental variables measured, fitted in the space of variation of macroinvertebrate composition. NMDS stress 0.186.

Table 4. Relations of vectors of environmental and substrate size variables with the NMDS

Environmental Variables	NMDS1	NMDS2	r2	Pr(>r)
d16	0.62368	-0.78168	0.2886	0.1019
d50	0.64899	-0.7608	0.2343	0.1698
d84	0.62352	0.78181	0.0698	0.6424
sg	0.06402	0.99795	0.171	0.3127
Temp_AV	0.24237	0.97018	0.2242	0.1978
pH_AV	0.10095	-0.99489	0.2843	0.1269

P values based on 1000 permutations.

Although no significant differences were found between the composition of functional feeding groups of the north and south bank deltas, shredders (invertebrates that chew pieces of living or dead plant material) and collector gatherers (invertebrates that use modified mouth parts to collect small particles (<1mm) accumulated on the bottom) were (Figures 8 and 9) considerably higher on the north bank.

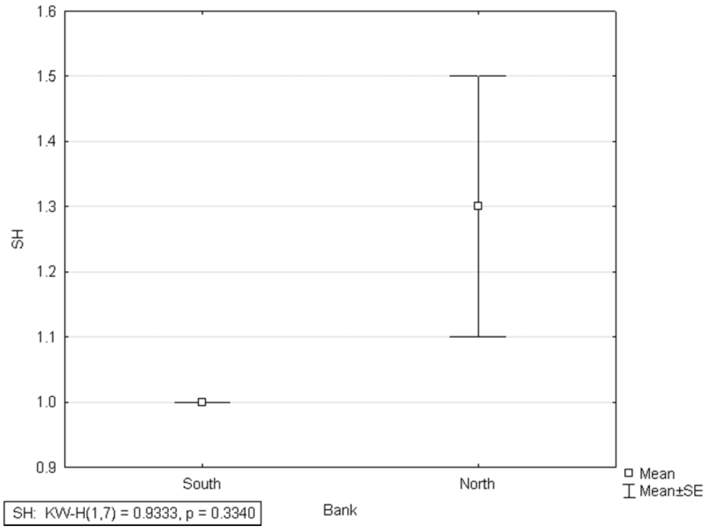

Figure 8. Shredder mean abundance at the south and north deltas at the San Juan River, Nicaragua.

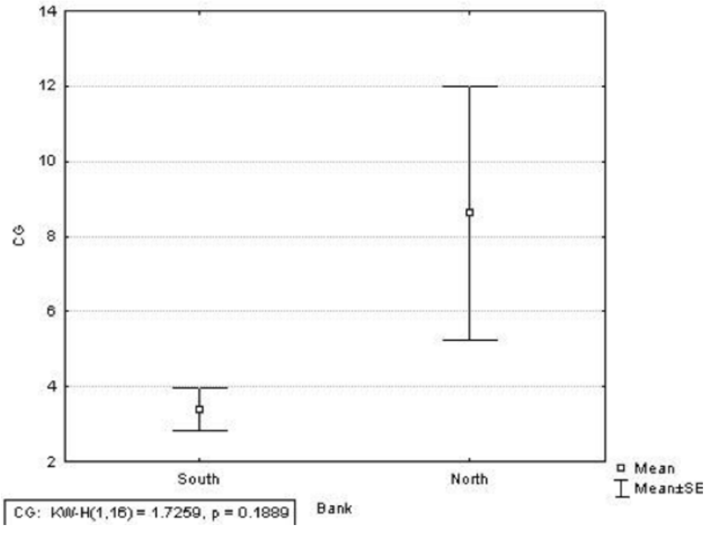

Figure 9. Collector-gatherer abundance at the south and north deltas at the San Juan River, Nicaragua**.**

4. Discussion

A. Periphyton Biomass Trends

Our results strongly suggest that the sediments eroded from the road are having negative effects on the aquatic communities of the deltas affected by the sediments. The effects documented here are on the benthic primary producers (periphyton), but would extend up the food chain (Wood and Armitage, 1997). We sampled during the dry season, when the deltas were more exposed by low water. With the first rains of the wet season, it is likely that runoff from the road would have an even stronger impact on the benthic communities.

These results are consistent with results of an exploratory study conducted in May 2013, involving collection of periphyton samples from 9 sites (as reported in Kondolf 2013). That study also showed striking differences in periphyton biomass on deltas receiving runoff and sediment from Rte 1856 contrasted with deltas of streams draining forested basins (Figure 4).

It is notable that the only samples that had to be eliminated for the analysis due to higher turbidity than those detected for Chlorophyll *a* were from south bank (i.e., road-impacted) sites. This is a further indicator that sediments are disrupting the periphyton habitat, consistent with the findings of other authors in similar situations (Lewis 1973a,b; Brookes 1986).

B. Macroinvertebrate Trends

As in previous studies assessing the consequences of abnormal inputs of sediments on river systems (Quinn et al. 1992; Fossati et al., 2001), we found a significant reduction of richness and abundance of macroinvertebrates. Richness and abundance of macroinvertebrates as well as the composition of the assemblages was clearly different from deltas draining the road at the south bank compared with the deltas draining the forest. These changes can have significant effects on the ecosystem, because of the reduction of prey availability for fish that feed on macroinvertebrates, and a reduction of the functions that these macroinvertebrates are performing on the ecosystem. EPT taxa reductions due to abnormal sediment inputs have been documented in several studies (e.g. Edwards, 2014). We also found this reduction trend on EPT taxa on the sites affected by the road, although it was not significant.

The influence of substrate size on the composition of the macroinvertebrate assemblages in the NMDS analysis suggest that habitat availability for macroinvertebrates is the main factor producing differences on the assemblages of deltas draining the road versus deltas draining forest (Figure 7). This agrees with the findings of Richards and Bacon (1994). But the observed reduction on periphyton biomass could also have consequences due to changes in food availability for macroinvertebrates as found in previous research (Cline et al. 1982, Peckarsky 1984 Graham 1990).

C. Macroinvertebrate Study Reported in Costa Rican Environmental "Diagnostic" Assessment

The macroinvertebrate study described in the "Environmental Diagnostic" report included as Annex 10 of the Counter-Memorial is flawed. First, the report is unclear regarding the sampling methods used. The report states that macroinvertebrate "collection is done over a total effort of 1 hour" (p.88, Vol. II:588). However, this is a much longer sampling period for use of a D-net than is normal. The document stated that the authors followed the methods stated in "MINAE 2007," but they failed to provide a citation for this publication in the References Cited. They were likely referring to a document entitled "Reglamento para la Evaluación y Clasificación de la Calidad de Cuerpos de Agua Superficiales," Decreto 33903, La Gaceta No. 178, San José, Costa Rica: MINAE, 7 pp. (MINAE 2007). This document recommends a 5-minute sampling per site, not an hour, as stated by the Environmental Diagnostic.

The Environmental Diagnostic report included no reference conditions for these type of rivers. This is a major failure since a reference condition (sensu Reynoldson et al., 1997) is required to have accurate results in biomonitoring programs (as stated, for example, for Europe in the Water Framework Directive, D.O.C.E, 2000). Moreover, no statistical tests were reported for impacted vs control sites, nor analyses to assess changes at the functional level of the community, even though this would be an obvious analysis to conduct on the data collected to assess the potential impacts of Rte 1856 (Henley et al., 2000; Rice et al. 2001).

Although substrate was cited as a main explanation for bio indicator variability, only one substrate size was presented per site, without explanation of how the values were obtained. The authors reportedly sampled sites in streams above and below road crossings of Rte 1856, but the Environmental Diagnostic presented no data to support the assumption that the sites were comparable except for the influence of the road. The maps did not have legends explaining the meaning of the various features appearing on them, and 11 sites appear on the maps, while only 10 were reported in the text.

The data presented in the Enivronmental Diagnostic actually indicated degraded conditions in sites downstream of the road (on sites 5-9), but the report still concluded the community was 'recovered' in the 1.5 years since the road work. Contrary to the assertion that the community had recovered from the impacts of the road, it is clear (not only from the results of our study, but even from the poor-quality study in the Environmental Diagnostic) that the road still has negative ecological effects on these creeks. Benthic communities have not reached 'stability' and are still suffering from the sediments coming from the road.

D. Sediment and Turbidity Effects on Periphyton and Macroinvertebrates

Professor Colin Thorne (in a report submitted to the International Court of Justice in December 2013 entitled *Assessment of the Impact of the Construction of the Border Road in Costa Rica on the San Juan River*) made the following statement: "Fish and other aquatic organisms in the Rio San Juan do not find high turbidity problematic because they are fully adapted to it." (Thorne 2013, p.50) Professor Thorne did not include any citations from the scientific literature to support his assertion. In response to Professor Thorne's assertion, we reviewed the scientific literature regarding the sensitivity to sediment and turbidity of macroinvertebrate species that occur in the Rio San Juan, and summarized relevant information in Table 4. There are at least 16 taxa of macroinvertebrates found in our study that are sensitive to suspended sediment increase and fine sediment deposition (nine of them highly sensitive). Also, there are sixteen EPT genera (Appendix 2, Fig XX), which are often considered as indicators of good water quality, sensitive to environmental changes (Chang et al., 2014; Carter and Resh, 2013) including fine sediment deposition (Edwards, 2014). These taxa occur with higher abundance on north-bank deltas than on south-bank deltas. The patterns we documented on the Rio San Juan are thus consistent with those documented in the scientific literature from studies in rivers elsewhere.

We also reviewed the scientific literature regarding sensitivity of primary producers, including periphyton, to sediment and turbidity. Wood and Armitage (1997) found at least 5 scientific studies demonstrating reduction of species diversity, productivity, biomass, and organic content due to increase of suspended sediments and deposition. The quantity of periphyton that grows on stream substrata is reduced through abrasion from sediment transport (Steinman and McIntire, 1990). This is evident in our study, where reductions of periphyton biomass draining the road are highly significant. Also increases in river turbidity limit light penetration and reduce phytoplankton production (Hoetzel and Croome, 1994). Reductions in both groups, primary producers (periphyton) and macroinvertebrates, can have severe effects on the upper trophic levels (e.g., fish) (Henley et al., 2010)

5. Conclusion

The available evidence demonstrates that the aquatic communities of the streams draining the road are significantly degraded compared to those developed on the deltas of tributaries entering the north bank of the river, which are not affected by the road-derived sediment. As a result, the biomass (periphyton) abundance and richness (macroinvertebrates) in the impacted sites are significantly less than those in the deltas unaffected by the road-derived sediment.

Table 4. Macroinvertebrate taxa found at the San Juan River deltas sensitive to suspended sediments (SS) and deposited fine sediment, according to scientific literature (ms = intermediate sensitivity; hs = high sensitivity).

Taxa	SS	Deposited Fine Sediment
Coleoptera		
Elmidae		ms(*)
Diptera		
Orthocladiinae		hs(+)
Simuliidae		
Simulium	ms(*)	
Tabanidae	hs(*)	
Ephemeroptera		
Caenidae		ms(*), hs(+)
Caenis	ms(*)	
Heptageniidae	ms(*)	
Leptohyphidae		
Tricorythodes		hs(+)
Leptophlebiidae		hs(*)
Gastropoda		
Ancylidae		ms(*)
Heteroptera		
Veliidae		ms(*)
Odonata		
Coenagrionidae		
Argia		hs(+)
Gomphidae	hs(*)	hs(*)
Plecoptera		

Perlidae		
Anacroneuria	hs(*)	hs(*)
Trichoptera		
Leptoceridae	ms(*)	ms(*)
Oecetis	ms(*)	hs(*)

(*) Carlise *et al.* 2007

(+) Zweig and Rabeni, 2001

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She has more than 10 scientific publications on ecology, diversity and monitoring of rivers. She worked for more than eight years at the Freshwater Ecology and Management Group at University of Barcelona in projects regarding to the implementation of the Water Framework Directive (WFD) in Mediterranean Rivers, the application of the WFD principles to Andean Streams, the definition of reference streams for Andean Rivers and basic ecology, taxonomy and life history of tropical aquatic insects. She has supervised several MSc theses in tropical biodiversity and ecology, and advised graduate students doing research on river restoration.

Appendix 1. Substrate and environmental characteristics of deltas sampled at the South (A) and North (B) banks of the San Juan River, Nicaragua.

Site	d 16	d50	d84	sg = $(d84/d16)^{½}$	Temperature (°C)	pH	Conductivity (µS/cm)
1A	7	7	7	1.00	26.9	7.84	185.17
2A	7	14.9	42	2.45	27.37	6.88	100.27
3A	7	17.3	48.7	2.64	27.9	6.83	133.33
4A	8.8	17.3	48.7	2.35	27.07	7.29	76
5A	7	11.5	19.5	1.67	28	7.73	226.7
6A	8	13.5	32	2.00	27.07	6.76	51.2
7A	8.8	15.4	38	2.08	26.27	6.89	59.43
8A	14	21.6	36	1.60	26.8	7.34	126.5
1B	10.8	17.5	31	1.69	26.27	7.13	74.73
2B	11	25.5	44.5	2.01	26.17	7.18	103.17
3B	9.6	13.8	21.7	1.50	26	7.25	93.97
4B	9.6	16.5	31	1.80	27.13	7.08	103.73
5B	9.6	14.5	26	1.65	25.33	7.89	74.2
6B	14.1	26.5	40	1.68	25.2	7.79	91.3
7B	7	10.2	24	1.85	25.37	7.59	56.03
8B	7	12	26.5	1.95	25.67	7.35	65.5

Appendix 2. Macroinvertebrates found at the North and South Bank deltas of the San Juan River, Nicaragua. Ephemeroptera, Plecoptera and Trichoptera (EPT), indicators of good water quality are marked in **bold.**

Site	Date	Order	Family	Subfamily / Genera	Abundance
1A	30/03/2014	Oligochaeta			3
1A	30/03/2014	Diptera	Chironomidae	Orthocladiinae	1
1B	31/03/2014	**Ephemeroptera**	**Baetidae**	***Americabaetis***	2
1B	31/03/2014	Heteroptera	Veliidae	*Rhagovelia*	2
1B	31/03/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	7
2A	30/03/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	2
2A	30/03/2014	Diptera	Chironomidae	Orthocladiinae (pupae)	10
2B	31/03/2014	**Ephemeroptera**	**Baetidae**	***Guajirolus***	1
2B	31/03/2014	**Ephemeroptera**	**Leptohyphidae**	***Leptohyphes***	2
2B	31/03/2014	**Ephemeroptera**	**Leptophlebiidae**	***Thraulodes***	8
2B	31/03/2014	**Ephemeroptera**	**Heptageniidae**	***Maccaffertium***	4
2B	31/03/2014	**Plecoptera**	**Perlidae**	***Anacroneuria***	2
2B	31/03/2014	Heteroptera	Naucoridae	*Limnocoris*	1
2B	31/03/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
2B	31/03/2014	Odonata	Gomphidae	*Phyllocycla*	1
2B	31/03/2014	Odonata	Coenagrionidae	*Argia*	4
2B	31/03/2014	Neuroptera	Sysiridae	*Climacia*	1
2B	31/03/2014	**Trichoptera**	**Hydropsychidae**	***Smicridea***	3
2B	31/03/2014	**Trichoptera**	**Odontoceridae**	***Marilia***	3
2B	31/03/2014	Diptera	Chironomidae	Chironominae	1
2B	31/03/2014	Diptera	Limoniidae	*Hexatoma*	1
2B	31/03/2014	Oligochaeta			1
2B	31/03/2014	Decapoda	Atyidae	Undet.	1
3A	30/03/2014	Odonata	Gomphidae	*Progomphus*	1
3A	30/03/2014	Diptera	Chironomidae	Chironominae (pupae)	1
3B	30/03/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
3B	30/03/2014	Diptera	Chironomidae	Tanypodinae	4
3B	30/03/2014	Diptera	Chironomidae	Chironominae	2

4A	30/03/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	1
4A	30/03/2014	**Ephemeroptera**	**Baetidae**	**Undet.**	1
4A	30/03/2014	Odonata	Gomphidae	*Progomphus*	2
4A	30/03/2014	Diptera	Limoniidae	*Hexatoma*	1
4A	30/03/2014	Diptera	Chironomidae	Chironominae	19
4A	30/03/2014	Diptera	Chironomidae	Tanypodinae	6
4A	30/03/2014	Diptera	Chironomidae	Tanytarsini	1
4A	30/03/2014	Diptera	Chironomidae	Orthocladiinae	4
4A	30/03/2014	Diptera	Ephydridae		1
4A	30/03/2014	Oligochaeta			1
4B	30/03/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	1
4B	30/03/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	1
4B	30/03/2014	**Ephemeroptera**	**Baetidae**	***Paracloeodes***	1
4B	30/03/2014	Diptera	Chironomidae	Tanypodinae	2
4B	30/03/2014	Diptera	Chironomidae	Chironominae	3
4B	30/03/2014	Oligochaeta			1
4B	30/03/2014	Gastropoda	Thiaridae	Melanoides tuberculata	1
5A	31/03/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	6
5A	31/03/2014	**Ephemeroptera**	**Leptophlebiidae**	***Farrodes***	2
5A	31/03/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
5A	31/03/2014	Odonata	Coenagrionidae	*Argia*	1
5A	31/03/2014	**Trichoptera**	**Leptoceridae**	***Oecetis***	1
5A	31/03/2014	Diptera	Chironomidae	Tanypodinae	5
5A	31/03/2014	Diptera	Chironomidae	Chironominae	6
5A	31/03/2014	Diptera	Chironomidae	Orthocladiinae	2
5A	31/03/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	3
5A	31/03/2014	Gastropoda	Ancylidae	*Gundlachia*	1
5A	31/03/2014	Gastropoda	Hydrobiidae	*Heleobia*	2
5B	31/03/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	2
5B	31/03/2014	Diptera	Chironomidae	Tanypodinae	6
5B	31/03/2014	Diptera	Chironomidae	Chironominae	7

5B	31/03/2014	Diptera	Ceratopogonidae	Ceratopogoninae	1
5B	31/03/2014	Diptera	Limoniidae	*Hexatoma*	1
5B	31/03/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	2
5B	31/03/2014	Oligochaeta			1
6A	30/03/2014	Diptera	Chironomidae	Chironominae	3
6A	30/03/2014	Oligochaeta			1
6B	1/4/14	**Ephemeroptera**	**Leptophlebiidae**	***Farrodes***	3
6B	1/4/14	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	7
6B	1/4/14	**Ephemeroptera**	**Leptophlebiidae**	***Maccaffertium***	1
6B	1/4/14	Odonata	Coenagrionidae	*Argia*	1
6B	1/4/14	Odonata	Gomphidae	*Perigomphus*	1
6B	1/4/14	Odonata	Platystictidae	*Palaemnema*	1
6B	1/4/14	Diptera	Chironomidae	Tanypodinae	8
6B	1/4/14	Diptera	Chironomidae	Chironominae	18
6B	1/4/14	Diptera	Chironomidae	Orthocladiinae	13
6B	1/4/14	Diptera	Simuliidae	*Simulium*	1
6B	1/4/14	Oligochaeta			1
7A	1/4/14	Oligochaeta			6
7B	31/03/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
7B	31/03/2014	Odonata	Coenagrionidae	*Argia*	1
7B	31/03/2014	Heteroptera	Veliidae	*Rhagovelia*	1
7B	31/03/2014	Diptera	Limoniidae	*Hexatoma*	1
7B	31/03/2014	Diptera	Chironomidae	Tanypodinae	4
7B	31/03/2014	Diptera	Chironomidae	Chironominae	4
7B	31/03/2014	Oligochaeta			14
8A	31/03/2014	Diptera	Chironomidae	Tanypodinae	1
8B	31/03/2014	Odonata	Gomphidae	*Progomphus*	1
8B	31/03/2014	Diptera	Chironomidae	Chironominae	1
8B	31/03/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	1
8B	31/03/2014	Oligochaeta			3
1A	27/04/2014	Oligochaeta			2

1B	27/04/2014	Heteroptera	Veliidae	*Rhagovelia*	1
1B	27/04/2014	Diptera	Limoniidae	*Hexatoma*	1
1B	27/04/2014	Diptera	Chironomidae	Chironominae	4
1B	27/04/2014	Diptera	Chironomidae	Tanypodinae	8
1B	27/04/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	10
1B	27/04/2014	Oligochaeta			19
1B	27/04/2014	Hirudinea			4
2A	26/04/2014	Odonata	Libellulidae	*Sympetrum*	1
2A	26/04/2014	Diptera	Limoniidae	Undet.	1
2B	27/04/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	1
2B	27/04/2014	**Trichoptera**	**Hydropsychidae**	***Leptonema***	1
2B	27/04/2014	Diptera	Chironomidae	Tanypodinae	5
2B	27/04/2014	Diptera	Chironomidae	Chironominae	8
3A	26/04/2014	Odonata	Gomphidae	*Progomphus*	1
3A	26/04/2014	Diptera	Chironomidae	Tanypodinae	1
3A	26/04/2014	Diptera	Chironomidae	Chironominae	1
4A	26/04/2014	Diptera	Chironomidae	Chironominae	1
4A	26/04/2014	Decapoda	Atyidae		1
4A	26/04/2014	Oligochaeta			1
4B	27/04/2014	**Ephemeroptera**	**Leptophlebiidae**	***Thraulodes***	2
4B	27/04/2014	Diptera	Chironomidae	Tanypodinae	91
4B	27/04/2014	Diptera	Chironomidae	Tanytarsini	65
4B	27/04/2014	Diptera	Chironomidae	Chironominae	31
4B	27/04/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	1
5A	27/04/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	2
5A	27/04/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
5A	27/04/2014	Odonata	Gomphidae	*Phyllocycla*	1
5A	27/04/2014	Heteroptera	Naucoridae	*Limnocoris*	1
5A	27/04/2014	Diptera	Chironomidae	Tanypodinae	6
5A	27/04/2014	Diptera	Chironomidae	Chironominae	6
5A	27/04/2014	Diptera	Ceratopogonidae	Ceratopogoninae	4

5A	27/04/2014	Ostracoda			3
5A	27/04/2014	Hirudinea			3
5B	26/04/2014	Diptera	Ceratopogonidae	Forcypomyiinae	3
5B	26/04/2014	Diptera	Ceratopogonidae	Ceratopogoninae	3
5B	26/04/2014	Diptera	Chironomidae	Tanypodinae	9
5B	26/04/2014	Diptera	Chironomidae	Chironominae	160
5B	26/04/2014	Diptera	Dolichopodidae	Undet.	1
5B	26/04/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	5
6A	26/04/2014	Diptera	Limoniidae	Undet.	1
6A	26/04/2014	Oligochaeta			4
6B	26/04/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	1
6B	26/04/2014	Odonata	Libellulidae	*Perithemis*	1
6B	26/04/2014	Diptera	Chironomidae	Tanypodinae	8
6B	26/04/2014	Diptera	Chironomidae	Chironominae	3
6B	26/04/2014	Diptera	Ceratopogonidae	Ceratopogoninae	2
7A	26/04/2014	Empty	Empty	Empty	Empty
7B	26/04/2014	Heteroptera	Gelastocoridae	*Montandonius*	1
7B	26/04/2014	Odonata	Libellulidae	*Perithemis*	1
7B	26/04/2014	Diptera	Chironomidae	Chironominae (*Stenochironomus*)	1
7B	26/04/2014	Diptera	Chironomidae	Tanypodinae	11
7B	26/04/2014	Diptera	Chironomidae	Chironominae	1
7B	26/04/2014	Oligochaeta			4
8A	26/04/2014	Diptera	Chironomidae	Tanypodinae	3
8A	26/04/2014	Diptera	Chironomidae	Chironominae	1
8B	26/04/2014	Diptera	Limoniidae	*Hexatoma*	2
8B	26/04/2014	Diptera	Chironomidae	Tanypodinae	1
8B	26/04/2014	Diptera	Chironomidae	Chironominae	2
9A	26/04/2014	Diptera	Chironomidae	Chironominae	2
9A	26/04/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	3
9A	26/04/2014	Oligochaeta			9
1A	14/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	1

1A	14/05/2014	Oligochaeta			1
1B	14/05/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	2
1B	14/05/2014	Odonata	Gomphidae	*Phyllogomphoides*	1
1B	14/05/2014	Coleoptera	Elmidae	*Heterelmis*	1
1B	14/05/2014	Diptera	Chironomidae	Tanypodinae	5
1B	14/05/2014	Diptera	Chironomidae	Chironominae	10
1B	14/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	3
1B	14/05/2014	Gastropoda	Ancylidae	*Gundlachia*	1
1B	14/05/2014	Gastropoda	Physidae		1
1B	14/05/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	113
1B	14/05/2014	Gastropoda	Pachychilidae	*Pachychilus*	2
1B	14/05/2014	Hirudinea			4
1B	14/05/2014	Oligochaeta			3
2A	13/05/2014	Odonata	Gomphidae	*Progomphus*	1
2A	13/05/2014	Diptera	Chironomidae	Tanypodinae	1
2A	13/05/2014	Diptera	Chironomidae	Chironominae	1
2B	14/05/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	4
2B	14/05/2014	Coleoptera	Elmidae	*Heterelmis*	1
2B	14/05/2014	Diptera	Chironomidae	Tanypodinae	7
2B	14/05/2014	Diptera	Chironomidae	Chironominae	5
2B	14/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	2
2B	14/05/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	1
2B	14/05/2014	Oligochaeta			3
3A	13/05/2014	**Ephemeroptera**	**Heptageniidae**	***Maccaffertium***	1
3A	13/05/2014	**Trichoptera**	**Hydropsychidae**	***Leptonema***	2
3A	13/05/2014	Diptera	Chironomidae	Chironominae	8
3A	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	2
3B	13/05/2014	Diptera	Chironomidae	Tanypodinae	8
3B	13/05/2014	Diptera	Chironomidae	Chironominae	3
3B	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	1
4A	13/05/2014	**Ephemeroptera**	**Leptophlebiidae**	***Farrodes***	3

4A	13/05/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	1
4A	13/05/2014	**Trichoptera**	**Hydropsychidae**	***Leptonema***	2
4B	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	5
4B	13/05/2014	Diptera	Chironomidae	Tanypodinae	32
4B	13/05/2014	Diptera	Chironomidae	Chironominae	53
4B	13/05/2014	Diptera	Chironomidae	Tanytarsini	6
4B	13/05/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	1
4B	13/05/2014	Hirudinea			1
5A	13/05/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	2
5A	13/05/2014	Diptera	Chironomidae	Tanypodinae	19
5A	13/05/2014	Diptera	Chironomidae	Chironominae	13
5A	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	4
5A	13/05/2014	Hirudinea			3
5B	13/05/2014	Diptera	Chironomidae	Tanypodinae	1
5B	13/05/2014	Diptera	Chironomidae	Tanytarsini	6
5B	13/05/2014	Diptera	Chironomidae	Chironominae	27
6A	13/05/2014	Empty	Empty	Empty	Empty
6B	13/05/2014	**Ephemeroptera**	**Leptohyphidae**	***Tricorythodes***	12
6B	13/05/2014	**Ephemeroptera**	**Caenidae**	***Caenis***	1
6B	13/05/2014	Coleoptera	Elmidae	*Heterelmis*	1
6B	13/05/2014	**Trichoptera**	**Hydroptilidae**	***Hydroptila***	1
6B	13/05/2014	Diptera	Chironomidae	Tanypodinae	2
6B	13/05/2014	Diptera	Chironomidae	Chironominae	1
6B	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	2
6B	13/05/2014	Hirudinea			1
7A	13/05/2014	Diptera	Simuliidae	*Simulium*	1
7B	13/05/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	2
7B	13/05/2014	Diptera	Chironomidae	Tanypodinae	2
7B	13/05/2014	Diptera	Chironomidae	Chironominae	1
8B	13/05/2014	**Ephemeroptera**	**Leptohyphidae**	**Undet.**	1
8B	13/05/2014	**Trichoptera**	**Leptoceridae**	***Nectopsyche***	1

8A	13/05/2014	Diptera	Chironomidae	Chironominae	4
8B	13/05/2014	Diptera	Chironomidae	Chironominae	5
8B	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	1
8B	13/05/2014	Diptera	Tabanidae		1
9A	13/05/2014	Diptera	Ceratopogonidae	Ceratopogoninae	1
9A	13/05/2014	Gastropoda	Thiaridae	*Melanoides tuberculata*	2

ANNEX 5

Dr. William R. Sheate, "Comments on the Lack of EIA for the San Juan Border Road in Costa Rica," July 2014

Comments on the lack of EIA for the San Juan Border Road in Costa Rica

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July 2014

1. Introduction

I have spent some 30 years working in the field of environmental impact assessment policy, regulation and implementation. I hold a Doctorate (PhD) on the basis of published work in environmental assessment law, policy and practice. I am an academic and a consultant practitioner. I am Reader in Environmental Assessment at Imperial College London (UK), Technical Director at Collingwood Environmental Planning Ltd (UK), an Honorary Senior Fellow at the University of Manchester (UK) and an academic panel member of Francis Taylor Building legal chambers in London. I was the Founding Editor (1998-2009) of the Journal of Environmental Assessment Policy and Management, published by World/Scientific/Imperial College Press, recognised as one of the leading journals in the field of environmental assessment. I have published over 100 academic and peer reviewed papers and books in the field. My expertise lies particularly in the field of environmental assessment policy, processes and implementation, including the application of assessment methodologies and public participation. My complete CV is attached as Annex I to this report.

As set out in my report below, it is my opinion that the lack of an EIA having been undertaken with regard to the construction of the Border Road by Costa Rica along the San Juan River runs counter to the normal expectations of international EIA practice, as set out in international legislation and best practice guidance.

I have reviewed the following materials in writing this report:

- Nicaragua Memorial Volume I and II, and in particular Annex 2, the 2012 Environmental Management Plan (EMP).
- Costa Rica Counter-Memorial Volume I and II, and in particular Annex 10, the Environmental Diagnostic Assessment (EDA).
- Relevant Ramsar and UNESCO designations.
- Costa Rica's Executive Decree Number 31849, "General Regulation regarding procedures for Environmental Assessment (EIA)", of 28 June 2004.

2. Executive Summary

For a road scheme of this length and scale in such a highly sensitive environment, the normal expectations, based on international best practice for the environmental screening of proposed projects, would be for an environmental impact assessment (EIA) to have been undertaken in advance of the decision of whether, where, and how to build the road – a project that clearly had and still has the capacity to cause significant environmental impacts. The Ramsar and UNESCO designations covering the San Juan River and adjacent areas should have been sufficient triggers on their own for an EIA or some form of advance assessment to have been undertaken. The scale of this international recognition, which is quite substantial, makes the absence of an EIA for a 160km road through a sensitive landscape all the more surprising. International screening guidelines for EIA strongly endorse the need for an EIA for a scheme of this scale and nature, and in such a receiving environment.

Costa Rica's EIA Regulation[1] appears, for the most part, to be consistent with international practice for screening, seeking to determine likelihood of significance and whether an EIA or some other form of ex ante assessment is required. However, unlike much international practice it does not make specific provision for emergency measures. Consequently, and notwithstanding the exemption decree[2], there appears to have been no attempt to undertake a lesser form of EIA in the event of an emergency situation being declared, as often provided for internationally.

The remediation activities highlighted in Costa Rica's Counter-Memorial, as well as related discussions in the Environmental Management Plan (EMP) and Environmental Diagnostic Assessment (EDA) – both commissioned by Costa Rica after the event – reveal the problems of Costa Rica not having undertaken a baseline study before the road was constructed, and the failure to anticipate potentially significant adverse environmental effects and make efforts to avoid, reduce or mitigate those effects prior to construction, especially in relation to the San Juan River. These problems confirm that an EIA was necessary for the project.

While the EDA, like the EMP, confirms the need for an EIA in this case, it is not a substitute for an EIA. In addition, its conclusion that the construction of the Border Road has had no impact on the San Juan River is unreasonable. The EDA effectively casts what might be

[1] Decreto 31849.

[2] Decreto 36440-MP.

considered, on their own terms, to be moderately significant impacts on Costa Rican territory as irrelevant impacts. Moreover, the idea that such impacts can be limited to Costa Rica's territory is not plausible, given the interconnectedness of the aquatic and other ecological systems in the area (one of the reasons for the multiple Ramsar designations).

Notwithstanding the emergency decree exemption for EIA, a simpler or rapid form of ex ante assessment, if not a full EIA, could still have been undertaken and should have been undertaken for construction of a road of this length in such a heavily designated sensitive environment.

3. The Purpose and Elements of EIA

EIA is widely established internationally as standard practice in relation to major developments likely to have a significant effect on the environment and as a preventive tool to avoid significant effects occurring in relation to sensitive locations. Some basic objectives, expectations and principles have been developed over time and are now reflected in most EIA regimes around the world. These have been well established in legislation and international agreements[3], as well as in the International Court of Justice judgment in 2010 in *Pulp Mills*[4]. EIA is also well established as part of the standard practices of international development banks and lending institutions, such as the World Bank in relation to bank funded projects[5].

This report addresses the normal expectations for EIA, as developed over the past 45 years through international agreements and typical EIA practice internationally and nationally. It does not seek to address the detailed and specific environmental impacts associated with the road construction, which are addressed by others, though observations are made where it is appropriate to compare practice in this case with best international practice in EIA processes. The report sets out at a theoretical level the nature, purpose and practice of EIA, as

[3] E.g. UNEP Principles on EIA, 1987; Rio Declaration 1992; Convention on Biological Diversity (CBD) 1992; European Union EIA Directive (originally 85/337/EEC, now consolidated as 2011/92/EU); UNECE Convention on EIA in a Transboundary Context 1991 (the Espoo Convention)); Ramsar Convention Impact Assessment Handbook 2010; UN General Assembly Resolution 2995 (XXVII), 1972; Agenda 21 (paras. 7.41 (b) and 8.4); the 1974 Nordic Environmental Protection Convention (art.6).

[4] Pulp Mills on the River Uruguay (Arg. v. Uru.), 2010 I.C.J. (Apr. 20).

[5] In the World Bank this is addressed through one of its ten Safeguard Policies and established as *Environmental Assessment in Operational Policy 4.01* (http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTENVASS/0,,contentMDK:20482652~menuPK:1182600~pagePK:148956~piPK:216618~theSitePK:407988,00.html). Environmental Assessment has been a formal Bank policy since 1989, and mandated the screening of Bank-funded projects for their environmental impacts, to include potential physical, biological, socio-economic and cultural resources impacts.

understood internationally as a benchmark against which to evaluate the lack of EIA in this case.

The intention of EIA is to provide information to the decision-making process so that the likely significant effects of a proposed development on the environment can be taken into account before the decision to proceed is taken and construction begins. EIA, therefore, is an essential tool to try to avoid adverse environmental impacts, and for mitigating any residual effects that cannot be avoided. To this end, EIA aims to implement the 'mitigation hierarchy' where a proponent should first seek to avoid adverse environmental impacts, then seek to reduce (mitigate) adverse impacts, and only as a last resort seek to remedy (compensate) for residual environmental impacts still remaining after avoidance and mitigation[6].

A key principle of EIA is that it needs to take place before decisions are taken to undertake or authorize activities likely to significantly affect the environment – early in the planning and project design process so that its findings can be taken into account in the design of the project as well as in the final decision on whether to proceed or not[7]. Central to EIA is the need to consider alternatives to the proposal[8] (e.g. alternative locations or routes, alternative design), as well as the potential cumulative effects of a proposal with other activities already taking place or likely to take place in the foreseeable future that may impact on important environmental receptors, such as sensitive habitats or species[9]. So for example, in the case of the San Juan Border Road, it is not just an issue of the environmental impacts of the road itself that is a concern, but also the potential cumulative impacts of the road with other activities that may affect the environment, including the San Juan River, e.g. through increasing levels of sedimentation that may enter the river from other rivers, including those from Costa Rica.

[6] E.g. EU EIA Directive 2011/92/EC Article 5 (3) (b); UNEP Online *EIA Training Resource Manual*, Topic 7, pp. 303-310, at http://www.unep.ch/etu/publications/EIA_2ed/EIA_E_top7_body.PDF.

[7] Ibid.

[8] Ibid.

[9] European Commission (2013) *Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment*, European Union Publications Office, 59pp, available at http://ec.europa.eu/environment/eia/pdf/EIA%20Guidance.pdf ; IAIA (2005) *Biodiversity in Impact Assessment*, Special Publication Series No. 3, available at http://www.iaia.org/publicdocuments/special-publications/SP3.pdf

EIA is recognised as a public process that facilitates public participation in environmental decision-making[10]; typically the public are given the opportunity to comment on the document that results from the EIA process – the environmental impact statement (EIS) or report – before the consent decision is made, and in many cases at earlier stages when the scope of the EIA process is being considered. Where there are transboundary effects, reciprocal arrangements are encouraged[11]. The aim of consultation and participation in the EIA process by the public and other authorities is to ensure that all potential significant effects are identified in advance of a consent decision and recognises that valuable and relevant knowledge about the environment is not the sole preserve of experts, but may be held by local communities, individuals, businesses, government agencies, non-governmental organisations (NGOs) etc.[12] It also provides a mechanism by which proponents and decision-makers can be held to account by the public[13].

It is essential that this assessment happens before a decision to go ahead is made, so that the likely significant effects can be taken into account at a time when it can make a difference, e.g. through re-design of the project, or locating the project elsewhere, or through integrating mitigation measures at the time of construction to minimise the impact on the environment.

These objectives are reflected in the core elements of any EIA process, which are:

- Screening
    - The process of deciding whether an EIA, or some other form of assessment, is required (discussed further below). Typically a decision of whether an EIA is required or not needs to be recorded, so that the reasons for requiring EIA, or a simplified form, or no EIA, are made public, are transparent and able to be scrutinised by those who have an interest.
- Scoping, consideration of alternatives
    - The identification of the key environmental issues and main environmental parameters for the assessment; the scope and scale at which those parameters

[10] Sheate, WR (1994), *Making an Impact: A Guide to EIA Law and Policy*, London, Cameron May (2nd Edition 1996); Wood, C (2003).

[11] Espoo Convention on EIA in a Transboundary Context 1991; Rio Declaration 1992 Principle 19.

[12] Sheate WR, and Partidário MR (2010, Strategic approaches and assessment techniques-Potential for knowledge brokerage towards sustainability, *Environ Impact Asses Rev*), 30: 278-288.

[13] Sheate WR (2012), Purposes, paradigms and pressure groups: Accountability and sustainability in EU environmental assessment, 1985-2010, *Environmental Impact Assessment Review*, 33:91-102.

should be considered, including the extent to which potential effects may extend beyond the boundaries of the development; and alternative options and processes, such as location and routes, materials and construction processes.

- Description of the environmental baseline
    - Environmental baseline data, to be gathered from existing data sets and new surveys where required, to provide the necessary description of the state of the environment against which predicted changes to be brought about by the proposed project can be assessed.
- Impact identification
    - The prediction of the likely environmental effects caused by specific aspects of the project on specific elements of the environment, and the potential for cumulative effects, resulting from combined aspects of the proposed project and possible interactions between the project and other projects in the vicinity.
- Impact assessment (significance) and mitigation
    - The assessment of the relative significance of the identified impacts, taking into account the size, nature and location of the proposed project, the sensitivity of the receiving environment and receptors (e.g. species, habitats, communities), the temporal nature of the predicted impacts (short, medium, long term, irreversible/reversible), and the extent to which effects can be mitigated.
- Report production
    - The process of documenting the findings of the assessment in an environmental impact statement (EIS, or similar), making it available alongside the application process for consent to the authority responsible for granting consent, and making it available for consultation with the public, stakeholders and authorities. On the basis of this assessment, an Environmental Management Plan (EMP) may be prepared (under some regimes) to provide the mechanism for implementing the mitigation measures identified[14].

[14] The UN University EIA On-line Training Course (section 7.4) indicates that: *"An environmental management plan (EMP), also referred to as an impact management plan, is usually prepared as part of EIA reporting. It translates recommended mitigation and monitoring measures into specific actions that will be carried out by the proponent. Depending upon particular requirements, the plan may be included in, or appended to, the EIA report or may be a separate document. The EMP will need to be adjusted to the terms and conditions specified*

- Consultation
  - Scrutiny of the EIS by the public, stakeholders, non-governmental organisations and other authorities, including by nationals and other interested parties of a neighbouring state where that is appropriate, given the potential transboundary nature of predicted impacts.
- Decision-making (decision whether to proceed or not)
  - Taking into account the findings of the EIS and the public consultation in deciding on whether the project should proceed or not, and if so what conditions and mitigation measures should be implemented.
- Monitoring
  - Monitoring and auditing of the predicted and other environmental effects of the project during and after construction and during operation, including putting in place measures needed to take remedial action in the event of significant unforeseen adverse effects.

The exact details, requirements and emphasis varies from regime to regime; not all elements are necessarily formalised requirements in all regimes, though the above would be recognisable as part of best practice[15]. Most importantly, however, the above highlights that EIA is a process that sets out a detailed procedure to be followed in order to ensure an adequate assessment is made of likely significant environmental impacts in advance of any decision of whether and how to proceed.

4. When is EIA Necessary?

As noted above, the process by which it is determined whether an individual proposed project requires an EIA is referred to as 'screening'. It is one of the critical issues in this case.

The central issue for screening generally (not just in relation to transboundary situations) is determining the likelihood of *significance*. The term is rarely defined under most regimes, but guidance is generally provided on the factors that contribute to significance and need to

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in any project approval. It will then form the basis for impact management during project construction and operation." http://eia.unu.edu/course/index.html%3Fpage_id=120.html.

[15] See for example, Wood, C. (2003), *Environmental Impact Assessment: A Comparative Review,* 2nd Edition, Harlow, Pearson, pp6-9; Lawrence, D.P. (2003) *Environmental Impact Assessment: Practical Solutions to Recurrent Problems,* New Jersey, Wiley, pp78-88; IAIA (2012), *Impact Assessment*, FasTips No. 1, available at http://www.iaia.org/publicdocuments/special-publications/fast-tips/Fastips_1%20Impact%20Assessment.pdf.

be taken into account in deciding whether significant effects on the environment are likely. Typically, the factors requiring consideration include, among other things:

- the magnitude (size or scale) of impact along with the geographical scope of the potential effects;
- the sensitivity of the receiving environment (e.g. whether the action will affect a designated site or sites, or designated/endangered species or habitats or important areas for biodiversity);
- whether there are likely to be cumulative effects that could be significant, even if individually effects might be insignificant;
- the temporal nature of impacts (i.e. how irreversible/reversible are the likely impacts); and
- the extent to which residual impacts can be mitigated[16].

One option for screening is that it can be undertaken on a case by case basis. This involves a project-specific assessment – to a greater or lesser degree – of the likelihood of significant effects stemming from the project. This assessment typically takes into account the considerations laid out above resulting in a decision of whether a full EIA, no EIA, or some simplified form of EIA is required. An example of this is the approach followed by the World Bank. The Bank classifies each proposed project by the type, location, sensitivity, and scale of the project and the nature and magnitude of its potential environmental impacts. Each classification carries with it different levels of EIA obligations. For a *Category A* project – one likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented, and which may affect an area broader than the sites or facilities subject to physical works – the borrower is responsible for preparing a report, normally an EIA. For a *Category B* project – one that has less adverse environmental impacts on human populations or environmentally important areas, and impacts that are more site-specific, reversible, and easily mitigated – the scope of EIA is narrower and unlikely to require a full separate EIA. Finally, *Category C* projects are those likely to have minimal or no adverse environmental impacts so that, beyond screening, no further assessment is required.[17]

[16] See Wood, C. (2003) and also Sadler (1996) *Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance*. Final Report, International Study of the Effectiveness of Environmental Assessment. Hull, Quebec, CEAA.

[17] World Bank Operational Policy (OP) 4.01 *Environmental Assessment*, para 8, available at http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/EXTPOLICIES/EXTOPMANUAL/0,,contentMDK:20064724~menuPK:64701637~pagePK:64709096~piPK:64709108~theSitePK:502184,00.html. As an

Screening can also be conducted through the use of lists of projects that are always subject to EIA (mandatory, inclusion lists), or can be subject to EIA subject to certain criteria and/or thresholds (discretionary lists), or are excluded in normal circumstances from EIA (exclusion lists)[18]. These lists reflect a determination, during their preparation, about what is likely to be 'significant', e.g. if over a threshold in terms of area, production capacity, or when particular criteria are met. As an example, the Espoo Convention on EIA in a Transboundary Context provides for both mandatory, inclusion lists (Appendix I, which lists projects that always require EIA) and discretionary lists focused on certain criteria (Appendix III, which provides general screening criteria for determining the environmental significance of a project). Appendix III criteria include, among other things, the scale of the project, the environmental sensitivity of the geographical areas likely to be affected, and the proximity to an international frontier.[19]

Many guidelines exist under specific national, regional or international regimes to support best practice EIA, including by identifying considerations relevant to determining the likelihood of significance.[20] The guidelines regarding EIA and biodiversity are of particular relevance in this case because of the relevant Ramsar designations with respect to the conservation of wetland wildlife. There is widespread recognition that EIA is critical to avoid adverse impacts on biodiversity and water resources, among other factors, and this is

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illustration, if the Border Road were subject to the World Bank Environmental Assessment procedures (which it is not), a Category A categorization might seem more likely given the length of the road, the sensitivity of the receiving environment, and the potential for impacts across a broader area than just the impact site (factors discussed below). However, the question as to whether the construction of the road would fall within Category A or Category B is somewhat academic, since in either case an ex ante assessment of some sort would be required, whether a full EIA or a simplified form of environmental assessment. It is clear that it would not fall into Category C because evidence already exists that the road has had adverse impacts, even according to the Environmental Management Plan (EMP) and Environmental Diagnostic Assessment (EDA) (discussed later).

[18] See Chapter 9 on screening in Wood, C (2003), *Environmental Impact Assessment: A Comparative Review,* 2nd Edition, Harlow, Pearson.

[19] Espoo Appendix III(a)-(d). For purposes of illustration, it appears unlikely that San Juan Border Road would meet the criteria for Espoo Appendix I projects (if Espoo were applicable in this case) simply because the road could not be classed as a motorway or express route under Appendix I, as such roads are typically 2-4 lane highways and paved. However I believe it to be indisputable that the characteristics of the project would satisfy the Appendix III criteria for requiring EIA, due to the road's scale, location in a sensitive environment, and proximity to Nicaragua.

[20] See for example guidance provided by the International Association for Impact Assessment: IAIA (1999), *Principles of Environmental Impact Assessment Best Practice*, available at http://www.iaia.org/publicdocuments/special-publications/Principles%20of%20IA_web.pdf and IAIA (2012), *Impact Assessment*, FasTips No.1 (April 2012).

reflected in the Rio Declaration[21], Agenda 21[22], the Convention on Biological Diversity[23] (CBD) and Ramsar Convention guidance[24].

In 2002 the CBD's Conference of the Contracting Parties at its 6th meeting (The Hague, The Netherlands, April 2002) endorsed draft guidelines for incorporating biodiversity-related issues into environmental impact assessment legislation and/or processes and into strategic environmental assessment (Decision VI/7-A). These 2002 CBD guidelines were also adopted by the Ramsar Conference of the Contracting Parties at its 8th meeting (Valencia, Spain, November 2002) with annotations describing their specific relevance to the Ramsar Convention (Resolution VIII.9)[25]. Among other things, the adopted Ramsar guidelines provide guidance on screening for EIA, i.e., guidance for determining the likelihood of significant effects and therefore whether an EIA should be required. Table 1[26] of the adopted guidelines is taken directly from the CBD Guidelines, and it relates specifically to screening for EIA and poses the sorts of questions or criteria that need to be considered in relation to biodiversity:

Table 1. Questions pertinent to screening on biodiversity impacts

Level of diversity	Conservation of biodiversity	Sustainable use of biodiversity
Ecosystem diversity *	Would the intended activity lead, either directly or indirectly, to serious damage or total loss of (an) ecosystem(s), or land-use type(s), thus leading to a loss of ecosystem services of scientific/ecological value, or of cultural value?	Does the intended activity affect the sustainable human exploitation of (an) ecosystem(s) or land-use type(s) in such manner that the exploitation becomes destructive or non-sustainable (i.e. the loss of ecosystem services of social and/or economic value)?
Species diversity *	Would the intended activity cause a direct or indirect loss of a population of a species?	Would the intended activity affect sustainable use of a population of a species?
Genetic diversity	Would the intended activity result in extinction of a population of a localized endemic species of scientific, ecological, or cultural value?	Does the intended activity cause a local loss of varieties/cultivars/breeds of cultivated plants and/or domesticated animals and their relatives, genes or genomes of social, scientific and economic importance?

(* The scale at which ecosystems are defined depends on the definition of criteria in a country, and should take into account the principles of the ecosystem approach. Similarly, the level at which "population" is to be defined depends on the screening criteria used by a country. For example, the conservation status of species can be assessed within the boundaries of a country (for legal protection), or can be assessed globally (IUCN Red Lists).)

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[21] Espoo Convention on EIA in a Transboundary Context 1991; Rio Declaration 1992 Principle 17.

[22] E.g. paras 7.41, 15.51, 18.40 among others.

[23] Article 14 (1).

[24] Ramsar Resolution VIII.9; Ramsar Handbook 16: Impact Assessment (2010), at http://www.ramsar.org/pdf/lib/hbk4-16.pdf..

[25] http://www.ramsar.org/pdf/res/key_res_x_17_e.pdf.

[26] Ramsar Handbook 16: Impact Assessment (2010), page 16, at http://www.ramsar.org/pdf/lib/hbk4-16.pdf.

The boxes that follow[27] provide Ramsar-specific annotations and include specific screening criteria that emphasise the importance of taking an ecosystem approach when evaluating a project proposed in or near a Ramsar site. Such an approach requires an understanding of ecosystem components and how those might be affected.

Ramsar:

Objectives - the objectives of the Ramsar Convention should be considered in the same way, i.e. promoting the conservation of wetlands, promoting the wise use of wetlands, and maintaining the ecological character of Ramsar sites.

The questions in Table 1 remain relevant, but at the ecosystem level two additional questions should also be asked concerning wetlands:

- Would the intended activity lead, either directly or indirectly, to an adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service of a wetland? (i.e. would it lead to a change in ecological character as defined under the Convention), and
- Would the intended activity constitute a use which would be 'unwise' in the sense of conflicting with the tenets of 'wise use of wetlands' as defined under the Convention, most recently in Resolution IX.1 Annex A.?

In a Ramsar context, the appropriate spatial scale at which to think about impacts may sometimes be a particularly broad-scale interpretation of "ecosystem". In particular, the river basin (water catchment) is an important scale at which to address aspects of wetland-related impacts. Also, where impacts on particularly important species such as migratory fish or birds, are at stake, assessment at the scale of the migratory range (flyway) of the relevant populations will be very relevant. This may involve a chain of ecosystems (perhaps disjunct ones), and therefore may need to take a broader perspective than would normally be the case under the ecosystem approach.

At the species diversity level - references to 'a population of a species' should include wetland species and migratory species. As a reference for populations, for waterbirds appropriate biogeographical populations are established in Wetlands International's periodically published *Waterbird Population Estimates*. For other taxa, population information regularly updated by IUCN's Specialist Groups though the IUCN Species Information Service (SIS) and published in the Ramsar Technical Report series should be used. Where a site regularly supports >1% of one or more populations of waterbirds or other wetland-dependent animal species, an additional question could be: would the intended activity threaten to cause a direct or indirect loss of the international importance of these interests at the site?

Genetic diversity – The Ramsar Convention does not currently directly address issues of genetic diversity.

[27] Ibid, pp16-17.

This annotation highlights the importance, when deciding whether an EIA is necessary in the Ramsar context, of thinking about impacts to the broader 'ecosystem', e.g. the river basin as a whole, in order to achieve Ramsar's objective of the wise use of wetlands[28].

An additional source of relevant guidelines is those pertaining to long, linear developments, which take on special significance in biodiversity hotspots. International Association for Impact Assessment (IAIA) guidance[29] highlights the necessity of extensive and highly detailed impact assessments for such projects. This is because the linear nature of a road causes effects to occur across the range of individual ecosystems and habitats the road passes through, and because cumulative effects can occur along the length of the road as a result of both construction and operation.

A review of Costa Rica's EIA regulation, Executive Decree Number 31849, of 28 June 2004, reveals the establishment of an EIA screening process that is consistent with the international practice described above[30], although other EIA regimes internationally often make explicit provision for emergency situations (see Section 7 below). Costa Rica has adopted a list-based approach to screening. Some projects, such as infrastructure development within wildlife refuges, are required by individual laws to include EIA[31]. Whether a full EIA, limited EIA, or no EIA is required for other projects is determined by whether the activity falls into category A, B1, B2, C, or outside any category as part of a classification scheme that considers the nature of the project and its potential environmental impact[32]. According to the text of Costa Rica's EIA Decree, the creation of this classification scheme was intended to embody the screening process as developed globally over the past decades, and illustrates many of the considerations described above[33]. For example, the scale of a project can determine in part the level of EIA required: construction of national roads more than 5 km long are deemed Category A projects, which require full EIA; those less than 5 km long are deemed Category B1 projects, which require creation of a more limited environmental

[28] Ramsar defines 'wise use' as follows: *"Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development."* (Ramsar COP9 Resolution IX.1 Annex A, page 6, para 22).

[29] IAIA (2012) *Impact Assessment*, FasTips No. 1.

[30] Note that a position is not being taken here as to whether or not Costa Rican law required an EIA of its own accord, only that Costa Rica has established a list-based approach to screening consistent with international practice.

[31] Decreto 31849, Annex I, p. 82.

[32] Decreto 31849, Annex II, p. 88.

[33] Decreto 31849, Annex II, p. 92.

management forecast/plan[34]. Classifications were also set based on a project's potential impacts - not only individual, but cumulative - on flora, fauna, and other biological resources, including through tree-cutting and impacts on forests or protected areas[35]. The particular care due in areas of high biodiversity is reflected in Annex III, which requires an EIA to take into special account impacts on environmentally fragile areas, such as a wildlife reserves and wetlands[36].

5. Why this Project Needed EIA

The starting point for considering whether the San Juan Border Road required EIA, notwithstanding the exemption decree (an issue discussed below), is thus to consider whether the Road would be likely to have significant environmental effects. It seems inconceivable that an EIA would not normally be required, taking into consideration the various factors that need to be considered in deciding whether significant environmental effects are likely. As discussed above, such factors can be found in international guidelines. Among the factors obviously relevant here are the nature and sensitivity of the receiving environment[37] (as indicated in its multiple international designations), as well as the sheer scale and nature of the project[38], two factors that combine to heighten the potential for irreversible and cumulative impacts[39].

A Sensitive Receiving Environment

The sensitivity of the receiving environment in this case is quite exceptional, as recognised by the swathe of not just national but international designations pertaining to the area. The following designations are of relevance to the San Juan River:

- **National**
  - *Nicaraguan*
    - Indio Maíz Reserve (1990)
  - *Costa Rican*
    - Refugio de Vida Silvestre Corredor Fronterizo (1994)

[34] Decreto 31849, Annex II, p. 105 (classifying road construction); Decreto 31849, art. 27 (requirements for Category A projects); Decreto 31849, art. 24 (requirements for Category B1 projects).

[35] Decreto 31849, Annex II, pp. 88, 89.

[36] Decreto 31849, Annex III, pp. 107-08.

[37] E.g. Ramsar IA Handbook (2010) No. 16, p.18; European Commission (1999), *Guidelines for the Assessment of Indirect and Cumulative Impacts and Impact Interactions*, Luxembourg: Office for Official Publications of the European Communities, pp.79-85.

[38] Ramsar Handbook (2010) p.19-20; European Commission (1999), *Guidelines for the Assessment of Indirect and Cumulative Impacts* pp. 73-78.

[39] European Commission (1999), *Guidelines for the Assessment of Indirect and Cumulative Impacts and Impact Interactions*, Luxembourg: Office for Official Publications of the European Communities, pp73-85.

- **International**
  - *Ramsar Wetland Convention*
    - Refugio de Vida Silvestre Rio San Juan (Nicaragua, 2001)
    - Humedal Caribe Noreste (Costa Rica, 1996)
    - Humedal Maquenque (Costa Rica, 2010)
    - Cano Negro (Costa Rica, 1991)
  - *UNESCO MAB Biosphere Reserve*
    - San Juan River – Nicaragua Biosphere Reserve (2003, incorporating Indio Maíz Reserve and Refugio de Vida Silvestre Rio San Juan).

Ramsar Convention designations are of particular relevance in the context of the Border Road and the San Juan River – the whole of the San Juan River is a Ramsar designation, and abutted by other Ramsar designations. The Ramsar citation for the San Juan River Refuge emphasises the importance of this site:

> ***'Refugio de Vida Silvestre Río San Juan**. 08/11/01; Río San Juan, Atlántico Sur; 43,000 ha; ca.10°56'N 083°40'W. Wildlife Refuge, Biosphere Reserve. A long, slender, convoluted site that follows the course of the Río San Juan, which flows from Lake Nicaragua at 32m altitude along the Costa Rican frontier 200km to the city of San Juan del Norte on the Caribbean coast, and includes the coastline to the north as well, part of the Biosphere Reserve Indio Maiz, **forming one of the two most extensive biological nuclei of the Mesoamerican Biological Corridor**. The site comprises an array of wetland types, including estuary and shallow marine waters, coastal freshwater lagoon, and intertidal marsh, as well as permanent lakes, rivers, and pools, inter alia. **Nearly all of the Ramsar Criteria are met, and four species of turtles, as well as the manatee Trichechus manatus, are supported**. Ramsar site no. 1138. Most recent RIS information: 2001.'* (emphasis added).

This and other Ramsar designations in the project's area of influence are particularly important and are worth understanding in more detail since alone, in my view, they should have been sufficient reason to require an EIA, and would be under many other regimes[40]. The Ramsar Convention[41] embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the "wise

[40] See for example Byron, H. 2000. *Biodiversity Impact - Biodiversity and Environmental Impact Assessment: A Good Practice Guide for Road Schemes*. Sandy, UK: The RSPB, WWF-UK, English Nature and the Wildlife Trusts; European Commission (2001) *Guidance on EIA Screening*, Office of Official Publications of the European Communities, Luxembourg; UNEP (2002) *EIA Training Resource Manual,* Topic 4 Screening, at http://www.unep.ch/etu/publications/EIA_2ed/EIA_E_top4_body.PDF.

[41] Convention on Wetlands (Ramsar, Iran, 1971) http://www.ramsar.org/cda/en/ramsar-home/main/ramsar/1_4000_0__.

use", or sustainable use, of all of the wetlands in their territories. The Ramsar mission is *"the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world"*[42].

The Ramsar International Cooperation Guidelines (1999) emphasise the importance of EIA in relation to Ramsar sites where there are shared wetland systems or obligations to consult other parties[43]:

> *"Administratively, it is also **essential that development proposals**, whether totally domestically funded, partly domestically funded, or totally foreign investment, **are subjected to impact assessment.**"* (emphasis added)

This is an emphatic recognition of the importance of EIA in preventing adverse environmental impact on the ecological character of a designated Ramsar site.

The existence of a Ramsar wetland reserve – because of their recognised international importance for wildlife conservation, and the expectation under the Ramsar Convention that EIA should be undertaken for development proposals that may affect Ramsar sites – should thus be sufficient to trigger an EIA where an activity might have potential for significant effects on it. Ramsar sites are designated by signatories to the Convention to confer recognition of their importance and a level of protection not afforded to non-designated sites. The likelihood of *significant* effects is increased because of the sensitive nature of the designated environment and the habitats and wildlife for which the area has been designated – the threshold for triggering EIA is therefore rightly expected to be much lower than if the receiving environment were not a Ramsar designated area (see Screening above). Practically, therefore, a precautionary approach should be adopted[44], i.e. if it is unclear whether there are likely to be significant effects on the environment, then some form of environmental assessment should be undertaken to determine whether a full EIA is required,

[42] Ibid.

[43] S.2.7.2, para. 62 *Guidelines for International Cooperation under the Ramsar Convention Implementing Article 5 of the Convention* adopted by Resolution VII.19 (1999) of the Ramsar Convention, available at http://www.ramsar.org/pdf/guide-cooperation.pdf.

[44] S.2.7.2, para. 62 *Guidelines for International Cooperation under the Ramsar Convention Implementing Article 5 of the Convention* adopted by Resolution VII.19 (1999) of the Ramsar Convention, available at http://www.ramsar.org/pdf/guide-cooperation.pdf.

so that any adverse impacts on the integrity and ecological character of the site can be avoided and/or minimised wherever possible.

In this situation the sensitivity of the environment is further enhanced by the fact that not only is the San Juan River Wildlife Refuge itself a Ramsar site – including the length of the river and the delta region – and abutted by a separate Ramsar site to the south, but that the whole area, including the San Juan River Refuge and the Indio Maiz Reserve, has been designated as a UNESCO Man and Biosphere Reserve since 2003[45]. Biosphere reserve designation is used only for the most important locations across 117 countries to create a coherent World Network of 621 reserves, and seeks to integrate cultural and biological diversity while supporting conservation, development and logistic support through zoning schemes, demonstration of sound sustainable development practices and policies based on research and monitoring, as well as acting as sites of excellence for education and training.

The UNESCO citation (designated in 2003) highlights why the Río San Juan Biosphere Reserve is so important:

> *'Covering 1,392,900 ha Río San Juan Biosphere Reserve is composed of seven protected areas and other adjacent territories.* ***The biosphere reserve covers an important variety of ecosystems representative of tropical humid forests and wetlands, tidal marsh, coastal lagoons and estuaries which are important shelters for rare or threatened animals and plant genetic resources of the meso-American tropics.*** *Furthermore the biosphere reserve includes a part of Lake Cocibolca and the municipalities of El Almendro, San Miguelito, Morrito and Nueva Guinea with a large (256,000 habitants) and culturally rich human population including 20,000 habitants of Rama, Miskitu, Negra and Creole ethnic groups.* ***Each one of these groups has its own way of preserving and/or using the national resources of the area.***
>
> ***The vast size of the biosphere reserve, in addition to its proximity to neighbouring Costa Rica protected areas, and as part of the Mesoamerican Biological Corridor, guarantee an adequate area for preserving genetic diversity, free mobility of species, breeding and maintenance of major species*** *such as the jaguar or american*

[45] UNESCO http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/.

tiger (Felis onca), the tapir (Tapirus biardii) and the red and green parrot (Psittacideae).' (emphasis added)

Clearly this is a very special location, home to sensitive biological resources and communities that would potentially suffer adverse impacts from any major activity undertaken immediately adjacent to the San Juan River. UNESCO Biosphere Reserve status recognises the important interaction between the maintenance of the natural environment and ecosystem processes and local inhabitants:

"Biosphere reserves are thus globally considered as:

- *sites of excellence where new and optimal practices to manage nature and human activities are tested and demonstrated;*
- *tools to help countries implement the results of the World Summit on Sustainable Development and, in particular, the Convention on Biological Diversity and its Ecosystem Approach;*
- *learning sites for the UN Decade on Education for Sustainable Development."*[46]

The use of "optimal practices to manage nature and human activities", and the implementation of the CBD and its ecosystem approach in accordance with UNESCO principles, both required EIA for the development of the San Juan Border Road. Without EIA, it cannot plausibly be claimed that the project has been or is being carried out in conformity with the highest international standards in environmental protection.

Scale of the Project in this Context

The scale of the San Juan Border Road (160km) and its proximity to the San Juan River for much of that distance are both factors relevant to the determination of significance[47]. To begin, a 160 km road construction project is a very large undertaking, with the potential to affect an extensive geographical area. Beyond the simple amount of land disturbance inherent in a project of that size, the long, linear nature of the road raises additional

[46] http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/.

[47] E.g. Ramsar Handbook No. 16 (2010) *Impact Assessment*, p.28ff; European Commission (1999), *Guidelines for the Assessment of Indirect and Cumulative Impacts and Impact Interactions*, Luxembourg: Office for Official Publications of the European Communities, pp.86-90.

concerns[48]. The length of the road means that it will pass through numerous individual ecosystems – the sensitivity of which is highlighted above. Moreover, the extensive construction activities required for a project of this scale in a sensitive environment also increase the possibility of cumulative effects along the length of the road, such as interactions between land take, disturbance caused by excavation and construction machinery and vehicles, atmospheric and water borne pollutants caused by construction and operation of traffic and machinery affecting specific vegetation and/or animal species.

The potential for a project on the scale of the Border Road to have significant impacts is heightened by its proximity to the Río San Juan River. At an initial level, proximity leads to a greater potential for significant impacts to the river. Additionally, the river has the ability to expand the area subject to the Border Road's potential significant impacts by transporting materials away from the direct area of influence. This includes areas downstream around the Delta, away from the immediate construction/operation activity of the road, which could be impacted through, for example, sediments and pollutants finding their way into the San Juan River and being deposited downstream where the flow of the river slows, potentially having an impact on aquatic wildlife and fluvial geomorphology in such locations.

Both the scale of the road and its proximity to the San Juan River thus suggest that an ecosystem scale consideration of the potential impacts to the Ramsar wetland system would be required. Even small disturbances – that individually may not appear to be significant – taken cumulatively along the length of the road, or of the River, can give rise to significant environmental effects and disturbance to the ecological character of the system. This is precisely the sort of project for which EIA was developed.

Demonstrated Impacts

The Counter-Memorial states that an EIA was not required because the road was not likely to have significant adverse effects on the environment and therefore did not require an EIA[49]. On the basis of the sensitivity of the receiving environment and surrounding areas I find this hard to accept. It is difficult to ascertain on what basis Costa Rica's judgment was made, when there appears to have been no screening process that could have informed that position. In the US, for example, one might expect an environmental assessment leading to a Finding

48 IAIA (2012) *Impact Assessment*, FasTips No. 1.

49 CRCM, para. 5.41(a).

of No Significant Impact (FONSI) – a much simpler form of assessment than the requirement to produce an Environmental Impact Statement (EIS) through a full EIA process.

Regardless, the claim that the road was not likely to have significant environmental effects is contradicted by the remediation activities undertaken by Costa Rica, as well as the findings of the Environmental Management Plan (EMP) and the Environmental Diagnostic Assessment (EDA).

Paragraph 2.38 of the Counter-Memorial indicates that "since April 2012, in order to protect the work that has been carried out so far and to mitigate the effects of the road (primarily in respect of Costa Rican territory), Costa Rica has been carrying out additional maintenance and remedial works on the Border Road." The list of remedial activities (a) to (t) in paragraph 2.38 highlights the significant adverse effects that have already required some remedial measures. Paragraph 2.40 of the Counter-Memorial goes on to explain that yet further remedial works are planned.

The fact that remedial works of this nature have been put in place and are planned for the future, irrespective of whether they are sufficient in themselves, is indicative of residual adverse environmental effects that have occurred as a result of the construction of the road alone, which should and could have been anticipated, and many of them prevented, had an EIA been undertaken in advance, and which Costa Rica regards as sufficiently significant to require remediation. Since no EIA or any other form of ex ante assessment was undertaken in advance of the decision of whether and how to proceed with the road, it is likely that remedial works will need to be greater than would have been required had avoidance measures and suitable mitigation measures been able to be designed into the construction process in advance, through the EIA process.

An Environmental Management Plan was published in April 2012 (2012 EMP) which was the result of an observational survey of the immediate effects of the road following construction. This document is not the same thing as the EMPs normally produced during an EIA process, as it was produced after the event, in the absence of any preceding EIA, when it could no longer guide the implementation of mitigation measures during the execution of the project. Nevertheless, even as a limited, rapid, post hoc survey, the 2012 EMP recognises that the construction of the San Juan Border Road has led to a range of adverse environmental impacts and a need for significant remedial measures[50]. In particular, the 2012 EMP identifies increased soil erosion, instability of slopes, and increased sedimentation as impacts already felt, among others[51]. It then proposes remedial measures to seek to contain these, including: sediment traps; the ceasing of dumping of excavation or cut material into rivers and brooks; measures to prevent fuel leaks; prohibition of machinery washing and maintenance in streams; and designation of construction waste and debris disposal sites[52]. Again, an ex-ante assessment would have been able to prevent many of these impacts through integrated good design, and avoidance and mitigation measures integrated into the project in the first place.

Notwithstanding its limitations (discussed below), the EDA provides similar evidence of existing impacts and the need for remediation[53] which could have been significantly avoided, had an EIA been undertaken.

Thus, the idea that an EIA was not necessary because construction of the San Juan Border Road was unlikely to have significant environmental effects is not only inconsistent with international practice regarding the screening for significance (as reflected in Costa Rica's own EIA regulation), but also with the remediation Costa Rica claims to be carrying out and the findings of the EMP and EDA. The project has already had significant adverse environmental effects on the basis of Costa Rica's own limited post hoc documentation, and will continue to have without the use of EIA.

6. The Environmental Diagnostic Assessment

The Environmental Diagnostic Assessment (EDA)[54] was commissioned by Costa Rica under administrative regulations, after the road had been constructed[55]. According to Costa Rica[56] "this type of study has two main objectives: first, to identify any negative impacts and risks of the activity on the environment; and second, to recommend environmental control

[50] EMP, pp19-27.

[51] Ibid.

[52] Ibid.

[53] Annex 10, CRCM Volume II, EDA pp. 144ff.

[54] Annex 10, CRCM Volume II.

[55] CRCM Volume I, Chapter 1.34.

[56] CRCM Volume I, Chapter 2.35.

measures necessary to prevent or to mitigate those negative impacts and risks." However, the EDA is a post hoc evaluation rather than an ex ante assessment.

Not a Substitute for EIA

The EDA is significantly flawed as an EIA substitute, not least because it cannot, by definition, do anything about avoiding impacts and can only seek to mitigate and remediate impacts after the event, but by then it is too late to prevent or even mitigate some environmental effects. Carrying out remedial works after the event is no substitute for avoiding impacts in the first place, which is the purpose of EIA – damage has already been done. An EIA would also have led to carefully considered answers to questions such as: What design standard is the road to be built to? Where is the spoil and debris as a result of the construction to be disposed of and how can the environmental effects of all these activities be avoided or minimised through the design or location of the road? These and similar issues are not – and could not usefully be – addressed in the EDA, which is therefore not a substitute for EIA, nor in any way equivalent.

The EDA is not even capable of being a meaningful auditing process, since there is an absence of a baseline against which to audit impacts. It is therefore – at best – a limited snapshot of the state of the environment of a limited area at the time of its undertaking, which include observations on the state of the environment as influenced by the effects of construction at the time of study.

The EDA is also deficient in its failure to consider issues such as possible impacts of run-off and sedimentation on the San Juan River and protected areas. Even in the limited area studied, the EDA focuses on ecological effects associated with the road, and does not address the wider range of environmental parameters that an EIA would consider, for example impact on local communities, air pollution, or cumulative effects of the road in association with other developments, existing or planned.

Neither does the EDA consider impact over time, such as the effects of *operation* of the road, or its long term effects, including consequential effects that may occur as a result of the road's existence (e.g. influx of people into the surrounding area facilitated by the new access, development and expansion of settlements, or the development of industry, such as mining projects or hotels, along the road), which in turn may have significant effects on the San Juan River through impacts on water quality and sediment load as a result of run-off and/or dumping of material into the river. The EDA only considers construction-related impacts. This is inconsistent with standard EIA practice, which normally considers the effect of operation of the road, including the nature and pattern of traffic/vehicle use, emissions of pollutants and their impacts, and the wider implications of the use of the road, especially in the proximity of a sensitive environment. For example:

- What might be the effect of run-off from the road into watercourses in the event of fuel oil or chemical spills? The road is a gravel road and therefore potentially susceptible to erosion from rainfall and flash flooding, which could increase the risk of vehicles coming off the road accidentally. What precautions have been taken to prevent vehicles and their fuel and cargo ending up in the San Juan River in such circumstances? And what type of vehicles will be using the road in the first place – will it be dominated by the use of lorries or small vehicles, for example?

- Gravel roads also give off dust under traffic which may have an impact on vegetation and biodiversity. Levels of dust can depend on the type of gravel used and the use or not of stabilizing compounds (chemicals, minerals, and resins) which are incorporated with the gravel[57]. These in turn could have their own impacts on the natural environment, e.g. as a result of run-off into watercourses and affecting aquatic plant and animal species.

A standard pre-project EIA would normally seek to address these wider issues well in advance. The EDA addresses none of them. For these reasons, too, it is no substitute for an EIA.

Unreasonable Conclusions of Low to No Impact

The EDA concludes that there has been no significant environmental impact on the San Juan River from the construction of the road. In my view, this conclusion is not reasonable for two separate but related reasons: it is based on an unreasonable interpretation of findings that were themselves produced through the use of a questionable assessment methodology.

[57] See, for example, US EPA guidance in relation to non-point source pollution in relation to roads at http://water.epa.gov/polwaste/nps/roadshwys.cfm#guide and http://water.epa.gov/polwaste/nps/upload/2003_07_24_NPS_gravelroads_sec1.pdf.

The EDA uses a modified Leopold Matrix to assess the impacts of the Border Road[58]. This is a pseudo-quantitative assessment methodology for interpreting the magnitude and significance of impacts, based on the assignment of numerical scores to what are actually qualitative determinations. There are two principal flaws in the application of this type of assessment methodology in this case.

The first is that it is being used *after* the event, not as a preventive assessment method. The problem stems from the lack of a baseline study against which to judge the assessment. The values used therefore cannot be traced through an audit trail to understand the basis of the scores allocated for each of the parameters – on what basis have these scores been allocated? I have no problem with expert judgment being used on the basis of good baseline information – there is then a basis on which to debate the details of the assessment. When qualitative scores are allocated (whether as numbers or as qualitative values such as high, medium or low) they should be justified by reference back to the anticipated/predicted change as a result of the (usually proposed) project. How can the EDA estimate the scale of change without knowing what may have changed and by how much? The answer is that it cannot.

The second problem with the way the matrix is used in the EDA is that it calculates a total score for key impact parameters based on magnitude (or intensity) and an array of factors that contribute to relative significance/importance – sensitivity, irreversibility, cumulative effects etc. The factors considered are appropriate, but I would take issue with the scoring system, particularly the lack of transparency as to how these scores were arrived at, and the way in which they have been interpreted in the EDA.

The summing of scores, as occurs in the EDA with the application of the standard model used in Costa Rica[59], generates a value which is assumed to be meaningful, because it appears to be quantitative. However total scores mean little in absolute terms – the numbers have no units – and only really have any value as relative numbers for comparing very similar alternatives against a baseline, i.e. before and after scores (notwithstanding that such a scoring system has its own inherent problems that need careful handling, as already noted).

[58] CRCM Volume II (Annex 10), EDA p.131.

[59] According to Decree No. 32967 - EDA, p.138.

The EDA uses pre-determined criteria for judging whether the total scores[60] for the assessed parameters are 'irrelevant', or of, 'moderate', 'severe' or 'critical' importance. It is not clear on what basis these pre-determined criteria have been devised. Nor is it clear the basis on which the scores have been assigned for each environmental component and each parameter of the scoring model – there appears to be no justification given for the scores assigned. They are, by definition, expert judgments and therefore the scores hide a significant degree of subjectivity, and lack transparency as to their basis.

The significance criteria are defined in the EDA as:

- *'Importance of impacts inferior to 25 makes them irrelevant.*
- *Importance between 25 and 50 means moderate impacts.*
- *Importance between 50 and 75 means severe impacts.*
- *Importance greater to 75 is a critical level of impact.'* (page 139, EDA)

The EDA finds only a few impacts that are of moderate importance (the maximum importance identified) with respect to Costa Rican territory:

- Deforestation along the right of way and contiguous areas
- Potential impact of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstices with sediment
- Possible impact on the quality of waters due to turbidity caused by sediment[61].

However, it is interesting to note that of the 11 parameters considered in Chart 23[62], *three* had scores that classed them as of moderate impact, and *five* scored -24 or -25 and were classed in the EDA assessment as *irrelevant*, even though this clearly makes them borderline or (in the case of the two at -25) even moderate impacts on their own criteria (above). So even on its own terms the interpretation of this scoring is highly questionable. To dismiss these borderline scores as irrelevant impacts highlights the risks of taking this kind of overly

[60] According to the application of the model I = ± [IN + 2 EX + MO + PE + PV + SI + AC + EF + PR + MC].

[61] CRCM Volume II (Annex 10), Chart 23, p.140 of the EDA.

[62] Ibid.

numerical approach, since there is a tendency to 'believe' the numbers and therefore not investigate more deeply to provide appropriate justification for those numbers on the basis of evidence of the degree of likely or actual significant change predicted or observed compared to a baseline.

An alternative interpretation of the same matrix is that of 11 parameters *five* were scored as having *moderate* impacts (from 25-50), with an additional *three* parameters *borderline moderate*, and only *three* with 'irrelevant' impact scores. That is quite a different interpretation even on its own terms – in fact it turns the assessment on its head – for most parameters the EDA finds the road construction as having had at least moderately significant impact. In its own terms, therefore, a justification for why an EIA should have been undertaken – significant effects have been observed.

The EDA did not assess impacts on the San Juan River or elsewhere in Nicaragua, apparently because access was not possible, although access to the River itself does not preclude the ability to make some assessment of possible impacts on the River. However, the EDA includes a matrix, on the same lines as for the Costa Rican territory, with respect to:

- Impact on aquatic habitat
- Potential impact of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstices with sediment
- Possible decrease in taxonomic abundance and richness
- Possible impact on the quality of waters due to turbidity caused by sediment
- Landscape impact due to the construction works

Because of no access to the River, the matrix (Chart 24, EDA, p. 142) is left blank, **but with 0 scores for each factor**. However, even though no assessment was undertaken, the EDA proceeds to conclude that

> ***'….it is not considered there could be any significant impact on the San Juan river'*** (page 141, EDA).

This is not a plausible conclusion, given the total lack of data available, according to the EDA, for the San Juan River. Even if the assessment of the road construction as presented in the EDA for the Costa Rican territory were accepted as having moderate impacts only for the three parameters identified (rather than the alternative interpretation above), in the absence of any other data to the contrary one might expect the EDA to at least have assumed a similar level of adverse impacts on the aquatic environment in relation to the San Juan River, especially given the Ramsar and UNESCO designations.

An absence of data does not mean an absence of evidence of impact. It is not uncommon for EIAs or other forms of assessments to have to deal with a lack of data. In such circumstances best practice would be to look for proxy indicators that could give an indication of possible trends in direction for key environmental parameters related to those for which data is not available. So in the absence of actual or recent data on sediment loads, for example, one might look at the scale, extent and nature of the types of activities that are known to increase sediment loads in watercourses, such as land clearance, use of heavy vehicles and excavation machinery and activities that disturb the soil and vegetation cover in the vicinity of water courses, e.g. deforestation. The impacts identified on Costa Rican territory due to the construction of the road, because of the activities involved in the construction, could be seen as just such proxy indicators that could be used to make an informed assessment. Even in the absence of proxy indicators an EIA or other assessment would have to rely on expert judgment, supported by a rationale for that judgment. However, the EDA makes no attempt to consider proxy indicators in relation to the *San Juan River*, nor does it attempt to offer an expert judgment with any justification. It simply draws the conclusion, on the basis of nothing, that there is no significant impact on the San Juan River. In my view, this undermines the credibility of the EDA.

Furthermore, the EDA does not conclude that there are no significant impacts at all from the road since it recognises at least that there are some moderately significant impacts from the road construction on Costa Rican territory, including on the aquatic environment and species due to turbidity and changes in water quality. In fact the EDA also claims a lack of data on the vulnerability of aquatic biota to sediment load increases in Costa Rica[63], but nevertheless proceeds to make an assessment of the impact on *Costa Rican territory* in the absence of such data. Given the interconnectedness of the aquatic systems in the area (one of the reasons for the multiple Ramsar designations), and that many of the Costa Rican watercourses flow into the San Juan River, impacts in Costa Rica clearly have the potential to also affect the San

[63] EDA, section 5.1.2.5.3, p111.

Juan River and Nicaragua. So on its own terms, how can it conclude *no* significant impacts on the San Juan River? That is simply illogical; and it becomes even more illogical if one interprets the matrix scores more appropriately according to their own criteria, since then the road would have had at least a moderately significant impact for the majority of 11 parameters examined in Costa Rica.

7. EIA in Situations of Emergency

The Counter-Memorial states that an EIA was not required because the road was classified as an 'emergency' measure and therefore exempt from EIA under Executive Decree 36440-MP.[64] The characterization of this issue, as well, is inconsistent with established international practice in EIA.

A number of EIA regimes across the world – the European Union[65], the United States of America[66], for example – have exemption clauses in relation to civil emergencies or projects associated with national defence, so Costa Rica's exercise of an emergency exemption[67] per se is not particularly unusual. The absence of any explicit provision for emergency exemption in the EIA Regulation[68] itself on the other hand is rather more surprising, or else the expectation is that there should be no emergency exemption from the EIA Regulation. In the case of the EU it is notable that the exemption cannot be utilised if the project concerned might affect another Member State, i.e. if there is likely to be a transboundary impact[69], since the Espoo Convention on EIA in a Transboundary Context (1991) does not allow for any exemption from EIA. In fact the use of exemption clauses tends to be very rare in practice, and generally where invoked exemptions tend to be used in relation to natural disasters and

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[64] CRCM Volume I, Para 2.27.

[65] EIA Directive 2001/92/EU, Article 2 (4) *"Without prejudice to Article 7, Member States may, in exceptional cases, exempt a specific project in whole or in part from the provisions laid down in this Directive. In that event, the Member States shall: (a) consider whether another form of assessment would be appropriate;…"*

[66] US NEPA 1969 CEQ Regulations Part 1506 , Sec. 1506.11 Emergencies.

Where emergency circumstances make it necessary to take an action with significant environmental impact without observing the provisions of these regulations, the Federal agency taking the action should consult with the Council about alternative arrangements. Agencies and the Council will limit such arrangements to actions necessary to control the immediate impacts of the emergency. Other actions remain subject to NEPA review. http://ceq.hss.doe.gov/nepa/regs/ceq/1506.htm#1506.11

[67] Decreto 36440-MP.

[68] Decreto 31849.

[69] European Commissions (2006), *Clarification of the Application of Article 2 (3) [as was] of the EIA Directive*, Luxembourg, European Communities, pp.10.

emergencies, e.g. in relation to earthquakes or flooding. For example, the Mount St Helens volcano eruption in the 1980s in Washington State, USA caused major flooding, river sedimentation, and adverse effects on fish and wildlife as well as on human settlements. The US Army Corps of Engineers - the lead federal agency to respond - invoked the 'special arrangements' provision of the CEQ's NEPA regulations, under which they were allowed to proceed immediately with certain river dredging and other emergency work while also conducting an accelerated EIA process. The Corps established an interagency working group, released a draft EIS for review and public comment in less than three weeks, and completed a final EIS in less than five weeks[70]. This illustrates that a rapid environmental assessment can be undertaken even in emergency situations.

Even assuming Costa Rica's declaration of an emergency was appropriate, the question is whether what was undertaken by Costa Rica was sufficient or appropriate given the nature of the project to be undertaken and the nature of the environment into which it was to be constructed. Even if a full EIA was not undertaken due to the declared emergency, e.g. because of insufficient time, what could reasonably have been expected to have been undertaken as an alternative to a full EIA? And was the post hoc Environmental Diagnostic Assessment sufficient?

A partial EIA could have been undertaken, and should have been, according to international practice; at the very least a rapid assessment of what the implications of the road might be for the Ramsar and UNESCO designated sites that could be affected (not even the Costa Rican sites were so considered). Specific international guidance, supported by UNEP and CARE International, along with other training resources, is available for undertaking just such rapid assessments in emergency and disaster situations[71]. The main guidelines document summarises the purpose of a rapid environmental assessment (REA):

> *"The REA is designed for natural, technological or political disasters, and as a best practice tool for effective disaster assessment and management. The REA does not replace an EIA, but fills a gap until an EIA is appropriate. A REA can be used from*

[70] Robert B Smythe, Potomac Resource Consultants, Chevy Chase, Maryland, USA September 10, 2012 Posting to ResearchGate Question: *How can the Environmental Impact Assessment (EIA) be used effectively when a disaster occurs?* Available at http://www.researchgate.net/post/How_can_the_Environmental_Impact_Assessment_EIA_be_used_effectively_when_a_disaster_occurs.

[71] ProAct Network website, Environmental Assessment and Environmental Action Plans, at http://www.proactnetwork.org/proactwebsite/environmental-assessments-and-environmental-action-plans.

> *shortly before a disaster up to 120 days after a disaster begins, or for any major stage-change in an extended crisis."*[72]

The construction of the road to date has taken more than three years and is still not complete, so lack of time to undertake even a preliminary assessment or rapid assessment that could have taken weeks or a few months would not seem to have been sufficient reasons to do nothing – something could have been undertaken in parallel with the early preparatory works to seek to avoid the worst of the likely significant environmental effects. Other regimes make provision for a modified form of assessment being possible under exceptional circumstances where a project is exempted from EIA[73]. There appears to have been no attempt to make alternative provision for some simplified form of ex ante assessment, even the equivalent of a screening decision that would have entailed some review of the likelihood of there being significant environmental effects.

It would also appear that there has been, and still is time to undertake an ex ante assessment of some form in relation to remaining works before completion of the road construction. Notwithstanding the emergency decree, the need to expedite – the rationale for such an emergency EIA exemption – would no longer seem to be relevant.

Given the international significance of the natural environment into which this road was being constructed, even in an emergency – and especially where the project has still not been fully constructed more than three years after it started – it is reasonable to expect some form of assessment of the potential impact on the environment. Even once construction had started some ex ante assessment could still be undertaken, particularly for those areas where the road has not yet been built.

8. Conclusions

In the case of the San Juan Border Road, because of its length and the sensitivity of the environment through which it is being constructed, its potential effects may operate at the ecosystem scale along the entire San Juan River, affecting the Ramsar wetland and other designations along its length. This could result in significant cumulative effects on the

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[72] Kelly, C (2005) Guidelines for Rapid Environmental Impact Assessment in Disasters, Benfield Hazard Research Centre University College London and CARE International, at http://www.proactnetwork.org/proactwebsite/media/download/resources/Ressource_Pack/REA_guidelines.v4.4.pdf.

[73] EIA Directive 2011/92/EU Article 2 (4)(a), for example.

designated site; even where some individual impacts themselves may not be significant, cumulatively and in conjunction with others they may become significant, which requires some form of ex ante assessment to determine; that is the critical role for EIA in such a case.

In the absence of EIA, Costa Rica is failing to assess the impact of the road on its own environment, not just that of Nicaragua. The Ramsar and UNESCO designations, and potential environmental impact of the road construction on those sites, should have been sufficient trigger to require EIA or some other form of ex ante assessment, due to its value to Costa Rica as well as Nicaragua. The San Juan River corridor is subject to joint international designations – they do not apply only to Nicaraguan territory – and as such should have had a significant bearing on Costa Rica's decision to build the road.

The EDA is not an acceptable alternative to the EIA – as a post hoc exercise it cannot substitute for an ex ante assessment before construction. The EDA, even on its own terms, provides an inadequate assessment of environmental impact of the road so far constructed. In the absence of appropriate data on the San Juan River it is simply not possible to conclude, as the EDA has, that the road has had no significant impact on the San Juan River and little impact in Costa Rica. This entirely undermines its credibility. The extent of the remedial works identified post construction, even in the limited 2012 EMP and EDA documents indicate that the road has had significant adverse effects in Costa Rica itself and so it is highly likely that it will have also had adverse effects on the San Juan River.

Since further construction work on the road is expected, if Costa Rica wishes to ensure the work is done to the highest international standards then a form of environmental impact assessment – whether full or simplified – is clearly essential before further work begins. In addition, further development projects in the future such as mining projects or hotel developments in the vicinity of the San Juan River, now possible given the access provided by the road, will need to be subject to their own EIA.

Curriculum Vitae

June 2014

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Personal Information

Born: 21 June 1961, Trowbridge, Wiltshire, UK
Nationality: British

Language	*Reading*	*Speaking*	*Writing*
English	5	5	5
French	3	2	2

Professional Profile

Originally an ecologist, Bill has worked, lectured and published widely on environmental assessment and policy for some 30 years. He has worked as a practicing ecologist, in consultancy, academia and in the voluntary sector. Most of his professional career has been spent working in interdisciplinarity. His experience lies in the development and application of environmental policy and legislation (especially EIA/SEA/SA) in the European Union, assessment procedures, methodologies, and public and NGO participation. He has been an expert advisor to the EC, the European Environment Agency, the UK, Irish and Uruguay governments, CPRE and the National Trust; was a board member of Transport 2000 and a long-standing member of the Environment Agency (and formerly National Rivers Authority) Thames Regional Committees; and has been involved in various committees of the International Association for Impact Assessment (IAIA). He has managed major studies for the European Commission DG Environment on SEA and Integration of the Environment into Strategic Decision-Making (2000/01); on the relationship between the EIA and SEA Directives (2004/5); and led an international team in the development and application of sustainability assessment of biodiversity management scenarios for declining agricultural areas in upland Europe (EU 5FP, 2002-5). Recent activities include research and practical SEA in Scotland and Wales; research in Ireland on the Water Framework Directive and its relationship with other environmental Directives; research for the European Environment Agency on scenarios, indicators and futures studies; SEA/sustainability appraisal for the Greater London Authority on the GLA's proposed Water Strategy and Climate Change Adaptation Strategy; SEA of River Basin Management Plans for the Environment Agency of England and Wales; and he was principal investigator for a for a ground-breaking Defra case study on ecosystem services and green infrastructure in the Thames Gateway (2008). He was a member of the UK’s first National Ecosystem Assessment (NEA) Urban Working Group and a co-author on the Urban chapter of the NEA. He is a co-investigator and senior advisor in two of the current NEA follow-on projects (2013). He is also a co-author of recent guidance for the European Commission DG ENV on EIA/SEA and climate change and biodiversity (2013) and currently leading the evaluation for Defra of the biodiversity offsetting pilot scheme in England (2012-2014). He is recognised as an international expert in advising on environmental assessment and compliance matters, e.g. for judicial review.

Bill has published extensively in the assessment and environmental policy field, and is the author of *Making an Impact: A Guide to EIA Law and Policy* (1994, 2nd edition1996) published by Cameron May, London and editor of *Tools, Techniques and Approaches for Sustainability: Collected Writings in Environmental Assessment Policy and Management* (2009), published by World Scientific. He is also the founding Editor (1999-2009) of the *Journal of Environmental Assessment Policy and Management* (ICP/WSPC), now in its 15th year. He has many years experience of teaching and training at advanced levels, and splits his time evenly between Imperial College London, where he is Reader in Environmental Assessment in the Centre for Environmental Policy, and Collingwood Environmental Planning, a specialist consultancy in environmental and sustainability assessment and policy. At Imperial College, for the last 16 years, he has been the Director of the highly interdisciplinary Core Course of the internationally renowned MSc in Environmental Technology, covering subjects as diverse as pollution control, risk assessment and ecology to environmental policy, economics and law. He has supervised some 15 PhD/research students and is a regular external examiner for MSc degrees and PhDs. He is also a member of the Academic Panel of Francis Taylor Building barristers' chambers (Inner Temple, London) and an Honorary Senior Fellow in the School of Environment and Development at the University of Manchester. He has, among others, ongoing research links with the, the Institute of Technology (IST) Lisbon and the Universities of Arizona State (USA), Waterloo (Canada), La Rochelle (France) and Göteborg (Sweden). In May 2008 he gave an invited speech to the ministerial high-level segment of the 4th Meeting of the Parties of the UNECE Espoo Convention on Environmental Impact Assessment in a Transboundary Context, in Bucharest, Romania. In March 2014 he was appointed Specialist Adviser to the House of Commons Environmental Audit Select Committee inquiry into HS2 (High Speed 2) and the Environment.

Qualifications/Awards

2011	PhD based upon Published Work, Staffordshire University: *Accountability in Environmental Assessment Law, Policy and Practice: Changing Paradigms, Changing Purposes in the European Union, 1985-2010*.
2002:	Award for Excellence in Teaching, Imperial College, University of London.
1984:	MSc, Environmental Technology; Diploma of Imperial College: Imperial College, London, UK
1982:	BSc (Hons) 2 (i), Biology (Ecology), University of Exeter, UK

Professional Associations

- International Association for Impact Assessment (IAIA)
- Green Alliance

Appointments

Date from-to	*Country*	*Company*	*Position*	*Responsibilities*
From Oct 2005:	London, UK	**Collingwood Environmental Planning**	**Technical Director** (p/t)	Senior member of CEP undertaking and managing consultancy in environmental and sustainability assessment policy and decision-making
From Oct 2005	London, UK	**Centre for Environmental Policy, Imperial College London.**	**Reader in Environmental Assessment** (p/t)	Deputy Director, MSc Environmental Technology (2002-) Director of Core Course, MSc Environmental Technology 1998 to date.
2003 to 2005:	London, UK	**Department of Environmental Science and Technology, Imperial College London.**	**Reader in Environmental Assessment**	Deputy Director, Environmental Policy and Management Group (EPMG) (2000-2005) Deputy Director, MSc Environmental Technology (2002-) Director of Core Course, MSc Environmental Technology 1998 to date.

1999 to 2003:	London, UK	**Department of Environmental Science and Technology, Imperial College London**	**Senior Lecturer in Environmental Impact Assessment (EIA)**	Deputy Director, Environmental Policy and Management Group (EPMG) (2000-2005) Deputy Director, MSc Environmental Technology (2002-) Director of Core Course, MSc Environmental Technology 1998-) Director of PhD Training Programme, Huxley School/DEST (1998-2002).
1995 to 1999:	London, UK	**Imperial College Centre for Environmental Technology (ICCET)**, Imperial College of Science, Technology and Medicine, University of London, UK	**Lecturer in Environmental Impact Assessment**	Member of the Environmental Policy and Management Research Group. Co-Director of Postgraduate Studies, ICCET (1997). Director of Core Course, MSc Environmental Technology (1998-) Director of PhD Training Programme, Huxley School/DEST (1998-2002).
1991-1994:	London, UK	**Imperial College Centre for Environmental Technology**, UK	**Visiting Lecturer in Environmental Assessment**	Lecturing on MSc Degree in Environmental Technology
1989-1994:	London, UK	**Council for the Protection of Rural England** (CPRE), UK.	**Senior Campaigner**	In various capacities during this period: Senior Campaigner: responsible for Environmental Assessment and Transport (1992-1994); Senior Campaigner: responsible for Environmental Assessment and Countryside Management (1991-92); National Campaigns Officer (1989-91); Water Campaigner - Parliamentary lobbying on the Water Bill 1989 (1989)
1989-1992:	Kingston, Surrey, UK	**Kingston Polytechnic**, UK	**Associate Lecturer in Environmental Assessment**	Lecturing on part-time MSc Degree in Earth Science and the Environment,
1987-1989:	Kingston, Surrey, UK	School of Geography, **Kingston Polytechnic**, UK	**Lecturer in Biogeography, Applied Climatic Studies and Environmental Assessment**	Diverse teaching to undergraduates of all years in Geography and Earth Sciences, and to postgraduates in Earth Science and the Environment; set up new part-time BSc degree in Environmental Studies; research and consultancy
1986-1987:	London, UK	**Lansdowne College**, London (American University College in London).	**Lecturer in Ecology and Environmental Studies**	Set up and taught two new elective courses in Ecology, and in Environmental Studies
1985-1986:	Dartford, Kent, UK	**Blue Circle Industries PLC**, UK	**Consultant Ecologist**	Ecological surveys and advice on proposed quarry sites and for existing landscaping schemes of quarry and cement works sites around the UK
1982-1983:	Exeter, UK	Department of Biological Sciences, **University of Exeter**, UK	**Demonstrator (p/t)**	Field work and practical teaching support in Freshwater, Marine and Terrestrial Ecology, Animal Behaviour and Paleoentology,

External Appointments

2014 Specialist Adviser to the **House of Commons Environmental Audit Select**

	Committee inquiry into HS2 (High Speed 2) and the Environment.
2013 -	External Examiner, **University of Strathclyde**, MSc/PG Dip Sustainability & Environmental Studies, MSc/PG Dip Environmental Entrepreneurship
2011 –	Chair, Environment Sub-committee, Editorial Advisory Board, **Imperial College Press**
2011-	External Examiner, **University College Dublin**, Republic of Ireland, MSc Environmental Resource Management and Diploma in EIA and SEA.
2010 - 2013	External Examiner, **University of Essex**, MA/MSc Environmental Governance: Natural World, Science and Society; MSc Natural Environment and Society; MSc Environmental Resource Management.
2009 -	Member of the UK National Ecosystem Assessment (NEA) Urban Working Group and a co-author on the Urban chapter of the NEA (**Defra, UK**).
2009 -	Member of Editorial Board, Journal of Environmental Assessment Policy and Management (formerly Editor and founder).
1998 to 2009:	Editor (and founder), **Journal of Environmental Assessment Policy and Management** (JEAPM), Imperial College Press/World Scientific Publishing, UK/Singapore (international journal exploring the linkages between environmental assessment and management approaches)
2007-	Honorary Senior Fellow, School of Environment and Development, **University of Manchester** (April 2007-)
2005 -	Member, Academic Panel, **Francis Taylor Building** (formerly 2 Harcourt Buildings) barristers' chambers, Inner Temple, London.
2007 - 2010	External Examiner, MSc Environmental Strategy, MSc Sustainable Development and MSc Corporate Environmental Management, **University of Surrey**, UK (2007-2010).
2006 - 2009	External Examiner, MSc in Environmental Impact Assessment, Auditing and Management Systems, **University of East Anglia**, Norwich, UK (2006-2009).
2000 to 2003:	External Examiner, MA Environmental Impact Assessment and Management, **University of Manchester**, UK.
2000 to 2006:	Examiner, **University of London External Programme** (distance learning), MSc Environmental Management.
1995 to 2002:	Member of the IAIA '96 Programme Committee (1995-96), International Co-operation Committee (1997-8), Task Force on Revenue Diversification (FORD) (2002), **International Association for Impact Assessment** (Executive Office in the USA)
1993 to 2002:	Member of the **National Trust's Transport Advisory Group** and **Transport Advisory Forum**, UK
1997 to 2000:	External Examiner, MSc Environmental Assessment, **University of Brighton**, UK.
1997 to 2000:	Member of the **Environment Agency** Thames North East Area Environment Group, UK (Statutory Regional Committee representative on new Area Group)
1996 to 2000:	Member of the **Environment Agency** Thames Regional Fisheries Ecology and Recreation Advisory Committee, UK (Statutory Committee under the Environment Act 1995)
1995 to 2000:	Member of the **National Rivers Authority** Thames Region Lower Lee Catchment Management Plan Steering Group, UK (now Environment Agency North London

Local Environment Agency Plan)

1995 to 1996: Member of **Natural Resources and Environment Panel, Technology Foresight Programme**, Office of Science and Technology/Department of Trade and Industry, UK

1994 Member of the Board of **Transport 2000**, UK

1991 to 1994: Member of the **National Rivers Authority** Thames Water Resources Strategy Consultative Forum, UK.

1990 to 1996: Member of the **National Rivers Authority** Thames Regional Rivers Advisory Committee, UK (Statutory Committee under the Water Act 1989, precursor to the Environment Agency)

Research Activities, Contracts and Consultancies

2014 - Project Director, Support to State and Outlook on the Environment Report (SOER) 2015 and Forward Looking Information Systems (FLIS) (June – December 2014). For **European Environment Agency** (EEA).

2014 - Project Director, Mapping of available and scoping of new indicators to meet monitoring needs of the 7th Environmental Action Programme (April- December 2014). For **European Environment Agency** (EEA).

2013 - Senior advisor, Monitoring and Evaluation of Nature Improvement Areas: Phase 2 (with the GeoData Insitute and Cascade Consulting). For the **Department for Environment, Food and Rural Affairs (**Defra). 2013 - ongoing

2013 Senior advisor, National BLOSSOM case study (Bridging Long-term Scenario and Strategy analysis - Organisation and Methods) for Switzerland: support to analysis for long term governance and institutional arrangements (with Milieu). For the **Federal Office for the Environment (FOEN) Switzerland.** 2013

2012-2013 Project Manager, Scottish Rural Develop Programme (RDP) Strategic Environmental Assessment (SEA) (as part of ex-ante evaluation led by Agra CEAS). For **Scottish Government**.

2012-2013 Senior expert advisor, Support to develop guidance for streamlining environmental assessment procedures of energy infrastructure 'projects of common interest' (PCI), **European Commission DG ENV/Energy**.

2012-2015 Senior advisor, Modular Development Plan of the Pan-European Transmission System 2050 - e-Highway 2050 (led by RDE). For **European Commission (FP7)**.

2012-2014 Principal Investigator/Project Manager, UK **Department for Environment Food and Rural Affairs** (Defra) project on 'Evaluation of Biodiversity Offsetting Pilot Scheme' (July 2012-June 2014) (with IEEP).

2012 Training Course for **Historic Scotland** "Ecosystem assessment and cultural heritage" – course leader for one-day in-house training course on how to address historic and cultural heritage issues within ecosystem approaches to EIA and SEA (September 2012)

2012 – 2013 Co-investigator, Capacities and Constraints to Embedding Consideration of Ecosystem Services in Policy Decision Making Through Appraisal - Work Package 8 of the **National Ecosystem Assessment (NEA)** follow up project (led by University of Exeter, with University of East Anglia). **UNEP/WCMC/DEFRA**.

2012 – 2013 Senior advisor, Tools: Applications, Benefits and Linkages for Ecosystems (TABLES) - Work Packages 9 and 10 of the **National Ecosystem Assessment (NEA)** follow up project (led by Birmingham City University). **UNEP/WCMC/DEFRA**.

2012	Training Module in Sustainability for **Veolia Group** Senior Managers (part of their international Managers Leadership and Development Programme): Course co-leader for 1.5 day intensive in-house training course run by Imperial College Centre for Environmental Policy. Run four times to date with further repetitions programmed.
2012–ongoing	Social Dimensions of Climate Change: Moldova, Azerbaijan and Armenia (with Acclimatise). For the **World Bank**. Expert Advisor on scenarios.
2011-12	Expert advice and review of Appraisal of Sustainability of High Speed 2 (HS2) for **Chilterns Conservation Board** and others.
2011-12	Project Director, Environmental Performance Review of Mexico – Climate Change, for **OECD/Foreign and Commonwealth Office (FCO)** (with Imperial College Consultants).
2011 – 2013	Senior advisor, "Measuring the impacts on global biodiversity of goods and services imported into the UK" research project for **Department of the Environment, Food and Rural Affairs (Defra)** (with SEI-York)
2011 – 2012	Support to developing Forward-Looking Information and Services (FLIS) – (Project Director) focusing on drivers and trends (drawing on the meetings of the Article 5 countries to further develop the FLIS Drivers and Trends component, revising and improving factsheets and incorporating additional information) and support to EEA in relation to Article 5 countries' work on scenarios and BLOSSOM - see below, (with Milieu and SEI) for **European Environment Agency** (EEA).
2011	Senior expert, **European Commission** project to prepare "Practical guidance and recommendations for integrating climate change and biodiversity into Environmental Impact Assessment (EIA) / Strategic Environmental Assessment (SEA) procedures" (with Milieu).
2011	Senior expert, **European Commission** study on "Assessing and Strengthening the Science and EU Environment Policy Interface" which is undertaking a detailed assessment of current methods and effectiveness of the science-policy interface in order help strengthen this interface within DG Environment to ensure more effective / appropriate use of scientific information in policy development (with Milieu).
2011-12	Project Director, Support to Forward Looking Information System (FLIS), **European Environment Agency** (with SEI/Milieu Ltd).
2011	Senior expert/QA for "*Knowledge Base for European Ecosystem Assessments*", **European Environment Agency** (with SEI-Stockholm).
2010-11	The natural environment and the proposed National Planning Framework for England - research on national level planning frameworks, including international case studies and expert interviews, to inform the **Royal Society for the Protection of Birds' (RSPB)** response to the UK Government's planning reform including Localism.
2010	Expert advisor to the Applicant in the judicial review: *Marco McGinty v Scottish Ministers,* (with Clare Twigger-Ross, CEP): report to Patrick Campbell and Company Solicitors *'Early and effective' participation in SEA, in the case of McGinty v Scottish Ministers*, November 2010.
2010	Project Director, BLOSSOM 3.0/SEIS 2.0 Support to developing SEIS Forward system and cooperation with EIONET, **European Environment Agency** (Collingwood Environmental Planning with SEI /Milieu Ltd).
2010	Principal Investigator, Support for SOER 2010 Part A – Global long-term environmental trends and ecosystem shifts and their (potential) impacts on human society, **European Environment Agency** (CEP with SEI/Milieu Ltd).

2009-10	Expert international advisor to "A methodology and project implementation framework for a Strategic Environmental Assessment (SEA) of the Spatial Development Plans (SDP) for eThekwini Municipality" (using ecosystem services) **eThekwini Municipality, Durban, South Africa/DANIDA.**
2009-10	Author of modules on environmental assessment and environmental management and auditing for MSc courses in Environmental Management/Sustainable Development by Distance Learning for **University of London External Programme**, School of Oriental and African Studies (SOAS), Centre for Development, Environment and Policy (CeDEP).
2009	Principal Investigator, Development of an Ecosystem Services Prioritisation Tool, research project for **Defra, Natural Environment Policy programme**, Collingwood Environmental Planning/Geodata Institute (October 2009-).
2009	SEA and energy policy, expert review and advice for **Royal Society for the Protection of Birds (RSPB) and WWF** (Oct-Dec 2009)
2009	Expert advisor on SEA to the applicant in the judicial review of **Irwin Glenbank Ltd v Department of Environment, Northern Ireland**.
2009	Developing the SEIS Forward system in support of environmental assessments. Project manager, **European Environment Agency** (with Milieu Ltd).
2009	Valuing Ecosystem Benefits: A Scoping Study, specialist advisor, **European Environment Agency**, (with eftec, Milieu Ltd,).
2008-2009	Project Manager/Principal Investigator, EEA Research BLOSSOM 2.0: Support to analysis for long-term governance and institutional arrangements, **European Environment Agency** (with Milieu Ltd) (2008/9), good practice case studies of futures thinking in selected EU Member States.
2009	Specialist advisor, **London Sustainable Development Commission**, developing guidance for integrated impact assessment (incorporating SEA, HIA) (with CAG Consultants).
2008	Review of SEA environmental reports and advice for **John Spain Associates**, Dublin.
2008	Review of SA reports and compliance of the UK Government's draft Planning Policy Statement on Ecotowns and Ecotowns Programme, for the **BARD Campaign**
2008	Expert advice reviewing SEA of Dublin Bay Masterplan, for **Treasury Holdings, Ireland** (2008) and expert advice reviewing EIA scoping report for North Lotts, Dublin Bay, also for Treasury Holdings, Ireland (2008)
2008-	Specialist advisor, Guidance on Assessing Cumulative Effects, **Natural England** (with LUC)
2007-2008	SEA Specialist, SEA of River Basin Management Plans (Thames, Anglian RBDs), **Environment Agency** (with Cascade)
2007	Expert evidence on EIA to **Government of Uruguay** in the case of Argentina v Uruguay (pulp mill) before the International Court of Justice
2007	Principal Investigator, *EEA Research Foresight for Environment and Sustainability*, **European Environment Agency** (with Milieu Ltd)
2007-2008	Supporting the Development of a Social Science Strategy for Flood and Coastal Erosion Risk Management (FCERM) R&D research, **Defra/Environment Agency** research project.

2006-2008	Principal Investigator and project manager, *Thames Gateway Ecosystem Services Assessment Using Green Grids and Decision Support Tools for Sustainability (THESAURUS*); case study in the **Defra Natural Environment Policy research programme** (Phase II) (October 2006-June 2008).
2006-	Sustainability Appraisal (incorporating SEA and Health Impact Assessment) of the **Greater London Authority's** *Water Strategy* - integrated appraisal for the GLA of their Water Action Framework (with CHERE), 2006 – 2010.
2006-	Sustainability Appraisal (incorporating SEA and Health Impact Assessment) of the **Greater London Authority's** *Climate Change Adaptation Strategy* - managing an integrated appraisal for the GLA of their Climate Change Adaptation Strategy (with CHERE), 2006 – 2010.
2006:	Member of Expert Review Panel evaluating research proposals under the Science for Sustainable Development 2nd Call for Proposals (Terrestrial Ecosystems), **Belgian Government Science Policy** (June 2006).
2006-2008	Specialist advisor, SEA of the Vision and Strategy for Wild Deer, **Deer Commission for Scotland** (with EnviroCentre)
2006	*Project Manager,* The Water Framework Directive, Assessment, Participation, and Protected Areas: What are the Relationships? (WAPPA), for the **Irish EPA** ERTDI Research Programme
2005-6	Principal Investigator, Review of future-related studies and analyses of uncertainties in the pan-European region, **European Environment Agency** (with Milieu Ltd)
2005-9	Specialist advisor, SEA Pathfinder Research Project, **Scottish Executive/Government** (with EnviroCentre), recommendations for good practice.
2005-6	Project Manager*, SEA of the Wales Rural Development Plan 2007-2013*, **Welsh Assembly Government** (with Agra CEAS)
2005 – 2008	Expert review panel member for SEA of Low Flow River Studies and Water Resources Management Plan, **Wessex Water plc**
2005 – 2006	Expert review panel member for EIA/SEA and water resources, **Thames Water plc/Cascade**
2004 – 2005	Project Manager/Principal Investigator for *The Relationship between the EIA and SEA Directives*, **European Commission, DG ENV.**
2004	Drafting of Policy Position Statement for the **Campaign to Protect Rural England (CPRE)** on ***Water*** (October 2004).
2003 – 2004	Member, SEA & Biodiversity Project Steering Group, **English Nature**, commissioning consultants to produce guidance on biodiversity and strategic environmental assessment.
2002 – 2005	*Principal Investigator and team leader for sustainability appraisal*: Scenarios for Reconciling Biodiversity Conservation with Declining Agricultural Use in the Mountains of Europe (*BIOSCENE*) project; **EU 5th Framework** funded project.
2002 – 2003	Expert Evidence on behalf of the **Irish Government (Department of Public Enterprise)** to the International Tribunal under the 1982 United Nations Convention on the Law of the Sea (UNCLOS), in the dispute concerning the MOX plant, international movements of radioactive materials, and the protection of the marine environment of the Irish Sea (IRELAND V UNITED KINGDOM)
2001 – 2002	Community and Public Participation: Risk Perception in Strategic Decision-Making in Flood and Coastal Defence, **Department of the Environment, Food and Rural**

	Affairs (DEFRA), with Scott Wilson Consultants.
2001 – 2004	*Principal Investigator*, Renewable Energy for Sustainable Rural Livelihoods – RESURL (in Cuba, Peru and Columbia), **Department for International Development** Research Contract.
2001 to date:	Member of Expert Panel for **European ECO Forum NGO Coalition** developing an SEA Protocol under the Espoo Convention on Environmental Impact Assessment in a Transboundary Context.
2000 – 2002	Member of research team commissioned by **Environment Agency National Centre for Risk Assessment and Options Appraisal** for a R&D project on *Strategic Integrated Assessment Methods*.
2001	*Project Manager* for **University of London External Programme** funded development project on Developing an Online Database and Course in EIA Law.
2000 – 2001	*Project Manager (for IC component)*, Use Classes Orders and the Integrated Transport Strategy, **DETR (with Baker Associates)**.
2000 – 2001	*Project Manager*, Strategic Environmental Assessment and Integration of the Environment into Strategic Decision-Making, **European Commission DGXI**.
2000	Member of Expert Review Panel for European Commission research contract on EIA and public participation for decommissioning of nuclear installations; **Nirex UK/EC.**
1999	Ongoing consultancy and advice to the **Environment Agency** on SEA and Appraisal.
1999 – 2000	Member of the Highways Agency NGO Committee for Multi-Modal Environmental Assessment Guidance Study; **Highways Agency/TRL**.
1999	Member of Expert Review Panel for European Commission research contract on EIA/SEA and public participation; **ERM/EC.**
1998 – 1999	*Project Manager*, Pan European Network of Environmental Legislation Observatories for Planning ,Education and Research (PENELOPE): web-based EIA resources and on-line course development, **DGXIII Telematics Programme**.
1998 – 1999	Member of Expert Review Panel for Public Information and Participation Chapter of the EU State of the Environment Report. **European Environment Agency**, Copenhagen, Denmark
	Member of Expert Review Panel for Strategic Environmental Assessment of Water Resources in the Thames Region. **Thames Water/Land Use Consultants**.
1997	Independent advice and review of draft environmental statement for the proposed Medway quarry and cement works in Kent. **Blue Circle Industries Plc.**
	Expert witness at the Public Inquiry into proposed military training intensification at Otterbun Training Area, Northumberland. **Council for the Protection of Rural England**.
1995 – 1998	*Czech Academic Links Project providing support and advice to a new University in North Bohemia* (JE Purkyne University), **British Council/Know How Fund Joint Coordinator**, Czech Republic.
1995 – 1996	Project Manager, *Analysis and Report to Natural Resources and Environment Panel, Technology Foresight Programme* **Office of Science and Technology/Department of Trade and Industry,** UK
1995	*Community Investors/ODA/Know How Fund Facilitation of input by Romanian NGOs to the National Environmental Action Programme,* **Romanian Government**, Romania

	Expert witness at the *Public Inquiry into the Proposal by UK Nirex Ltd for a Rock Characterisation Facility*, Longlands Farm, Gosforth, Cumbria (October). **Friends of the Lake District** (FLD), UK
	Convenor of workshop on *public and NGO participation in the EIA process*, **International Association for Impact Assessment,** Durban, South Africa
1995 – 2004	Co-ordinator, **EIA Training and Research Network (ETAR)** and web page, UK
1994	Expert Advisor to the European Communities' Economic and Social Committee's study into the *proposed amendments to the EIA Directive 85/337/EEC*, **European Communities**, Europe
	Member of the European Commission's Hearing of Experts Panel (DG VII, Transport) on the *Strategic Environmental Assessment of the Trans-European Network for Transport,* **European Commission**, Europe Briefing document on the *European Commission's proposed changes to the EIA Directive (85/337/EEC),* **European Environmental Bureau ,** Europe
1993	Chaired workshop on *Legislating for EIA,* **International Association for Impact Assessment**, Shanghai, China, International
	Oral and Written Evidence to the study by Sub-Committee B on the EC's Common Transport Policy, **House of Lords European Communities Select Committee**, Europe/UK
1992	Invited round-table member of *What Environmental Institutions Does the UK Need?* Round-table Conference, **London School of Economics and Political Science**, UK
	Expert witness to the Public Inquiry into the North Yorkshire Power Lines proposal by National Grid Plc, **Council for the Protection of Rural England**, UK
	Oral Evidence to the RCEP's study: Transport and the Environment, **Royal Commission on Environmental Pollution (RCEP),** UK
1991 – date	*Teaching link and annual supervision of US postgraduate placement students (5-month placements) in comparative environmental law, EIA, SEA, landscape protection and forestry,* **Boston College Law School,** US (1991-2005, 2009-)
1990	Member of Expert Review Panel advising the Countryside Commission on *draft guidance note on the treatment of Landscape and Recreation in Environmental Assessment,* **Countryside Commission**, UK
1990 – 1996	*Trainer for annual workshops/short courses on EIA for CPRE branch and NGO staff and volunteers,* **Council for the Protection of Rural England,** UK
1988	Report on the *Ecological Status of Heath Warren/Warren Heath Proposed Nature Reserve,* Hampshire, **Bioscan (UK) Ltd**, UK
1986	Report on *The Status of Tree and Shrub Planting Activities at Selected UK Quarry and Cement Works' Sites.* **Blue Circle Industries Plc.** UK
1985	Report on the *Ecological Status of Potential Chalk Quarry Sites in North West Kent*. **Blue Circle Industries Plc**. UK
1984 – 1985	*Technical editing of report on East-West Environmental Law and Policy*. **Vienna Centre**, Austria
1982 – 1983	*Indexing of book, Social Insects: Ecology and Behavioural Biology* by **M.V. Brian**, UK

External Training Courses
(run as member of Collingwood Environmental Planning)

Training Module in Sustainability for Veolia Group Senior Managers (part of their international Managers Leadership and Development Programme): Course co-leader for 1.5 day intensive in-house training course run by Imperial College Centre for Environmental Policy. Run four times to date with further repetitions programmed in 2013.

Training Course for Historic Scotland "Ecosystem assessment and cultural heritage" – course leader for one-day in-house training course on how to address historic and cultural heritage issues within ecosystem approaches to EIA and SEA (September 2012)

SEA training course –SEA course - ***Strategic Environmental Assessment: Implementation in Practice*** - run in 2004 (five days), 2005 (four days), 2006 (3 days), 2007 (3 days), 2008 (3 days), 2009 (3 days) , 2010 (3 days) and attended by agencies and authorities, international organisations, e.g. World Bank, UNEP and participants from other EU Member States. **Imperial College London/CEP** (2004 to date).

Sustainable Strategies: Tools for Effective Practice – 1-day course on the use of strategic assessment tools in the development of sustainable strategies and plans (stand alone or as add-on to SEA course). **Imperial College London/CEP** (2008).

Climate Change Adaptation: Drivers, barriers and strategy – *2-day* continuing professional development course for local authorities and other agencies developing climate change adaptation strategies (March 2009, 2010, 2011).

Sustainability Appraisal of Local Development Documents (LDDs) training course (2 days). Provided in-depth and practical knowledge of the process of Sustainability Appraisal and how to implement the requirements with regard to LDDs. Run jointly with Imperial College London. October 2006.

Tailor-made training courses on SEA/SA*,* e.g. for Association for London Government; Hounslow Borough Council; Government of Cyprus; Government of Greece.

Publications (full list)

Books

1. SHEATE, W R (2009), *Tools, Techniques and Approaches for Sustainability: Collected Writings in Environmental Assessment Policy and Management*, World Scientific: Singapore, pp.408 (October 2009).

2. SHEATE, W R (1996) *Environmental Impact Assessment: Law and Policy - Making an Impact II* (2nd edition), Cameron May, London. 300pp

3. SHEATE, W R (1994) *Making an Impact: A Guide to EIA Law and Policy*. Cameron May, London, UK. 260pp.

4. SHEATE, W R and Sullivan, M (1993) *Campaigners' Guide to Road Proposals.* Council for the Protection of Rural England, London, UK. 148pp.

Software

5. SHEATE, W (2011) *Environmental Assessment (C207)* Module and Study Guide, Distance Learning Programme, CeDEP/SOAS, University of London

6. SHEATE, W (2011) *Environmental Auditing and Environmental Management Systems (C208)* Module and Study Guide, CeDEP/SOAS, University of London.

Articles, Chapters and Papers

7. SHEATE, W.R and Eales, R. P (in press), Effectiveness of European national SEA systems: How are they making a difference? Chapter in Sadler, B. and Dusik, J., (Eds.) *European and International Experience of Strategic Environmental Assessment: Recent Progress and Future Prospects,* Earthscan.

8. Turnpenny, J. Russel, D., Jordan, A., Bond, A. and SHEATE, W. (in press) "Environment", Chapter in Dunlop, C.A. and Radaelli, C.M. (Eds*.) Handbook of Regulatory Impact Assessment*, Oxford Handbooks.

9. SHEATE, W.R. (in press, 2015) Streamlining SEA Processes, Chapter in Jones, G and Scotford, E. (Eds.), *The Strategic Environmental Assessment Directive: A Plan for Success?* Hart Publishing.

10. SHEATE, W.R and Baker, J (in press, 2015) Ecosystem services assessment and sustainability, Chapter in Morrison-Saunders, A., Pope, J. and Bond, A. (Eds.) *Handbook of Sustainability Assessment,* Edward Elgar.

11. Partidário MR, SHEATE, W., (2013), "Soutenabilité et évaluation environnementale stratégique: fusions théoriques et interdisciplinarité" In:"l'évaluation de la soutenabilité", QUAE éditions; Versailles, France.

12. Baker, J., SHEATE, W.R., Philips, P. and Eales, R. (2013) Ecosystem services in environmental assessment – help or hindrance? *Environmental Impact Assessment Review* Vol:40, Pages:3-13.

13. Fazey I, Evely AC, Reed MS, Stringer, LC , Kruijsen J, White PCL, Newsham A, Jin L, Cortazzi M, Phillipson J, Blackstock C, Entwhistle N, SHEATE W, Armstrong F, Blackmore C, Fazey J, Ingram J, Gregson J, Lowe P, Morton S, Trevitt C (2012), Knowledge Exchange: A Review and Research Agenda, *Environmental Conservation*, 40 (1): 19–36

14. Partidário M.R., and SHEATE, W.R. (2013), Knowledge brokerage - potential for increased capacities and shared power in impact assessment, *Environmental Impact Assessment Review*, 39: 26–36.

15. SHEATE, W.R., Eales, R.P., Daly, E, Baker, J, Ojike, U, Karpouzoglou, T., Murdoch, A. and Hill, C (2012) Spatial Representation and Specification of Ecosystem Services: a Methodology Using Land Use/Land Cover Data and Stakeholder Engagement, *Journal of Environmental Assessment Policy and Management,* Vol:14, Pages:1-36.

16. Campbell, G., SHEATE, W.R., (2012), Embedding an ecosystems approach? *Town and Country Planning,* Vol: 81, Pages: 139-144.

17. Allen, J., SHEATE, W.R., Diaz-Chavez R., (2012), Community-based Renewable Energy in the Lake District National Park – Local Drivers, Enablers, Barriers and Solutions, *Local Environment: The International Journal of Justice and Sustainability*, available online 16 March 2012, doi:10.1080/13549839.2012.665855.

18. SHEATE, W.R., (2012), Purposes, Paradigms and Pressure Groups: Accountability and Sustainability in EU Environmental Assessment, 1985-2010, *Environmental Impact Assessment Review*, Vol: 33, Pages: 91-102.

19. SHEATE, W.R., Daly, E., White, O., Zamparutti, T. and Baker, J. (2011) BLOSSOM — Bridging long-term scenario and strategy analysis: organisation and methods: A cross-country analysis, EEA Technical report No 5/2011, main report (and 12 Country Annexes) available at http://www.eea.europa.eu/publications/blossom/ [accessed 21 October 2011].

20. SHEATE, W.R. (2011), *Accountability in Environmental Assessment Law, Policy and Practice: Changing Paradigms, Changing Purposes in the European Union, 1985-2010*. PhD based upon Published Work, Staffordshire University.

21. Davies, L., Batty, M., Beck, H., Brett, H., Gaston, K.J., Harris, J.A., Kwiatkowski, L., Sadler, J., Scholes, L., SHEATE, W.R. and Wade, R. (2011), Chapter 10, Urban Broad Habitat, in *UK National Ecosystem Assessment*, Defra, available at http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx [accessed 19 October 2011]

22. Eales R P and SHEATE W R, (2011), Effectiveness of Policy Level Environmental and Sustainability Assessment: Challenges and Lessons from Recent Practice, *Journal of Environmental Assessment Policy and Management*, 2011, Vol:13, Pages:39-65.

24. SHEATE WR, Eales R, Baker J, Stafford J, Barker A, van der Burgt N, Partidario MR (2011), *A Natural Planning Framework: Putting the natural environment at the heart of the National Planning Framework for England*, RSPB, February 2011.

25. Zhou, K. and SHEATE, W.R. (2011) EIA application in China's expressway infrastructure: clarifying the decision-making hierarchy, *Journal of Environmental Management,* 92 (6): 1471-1483; doi: http://dx.doi.org/10.1016/j.jenvman.2010.12.011

26. Zhou K, And SHEATE WR (2011) Case studies: Application of SEA in provincial level expressway infrastructure network planning in China — Current existing problems, *Environmental Impact Assessment Review*, 31(6): 521–537,doi: http://dx.doi.org/10.1016/j.eiar.2010.10.005

27. SHEATE, W.R. (2010), Linking SEA and Environmental Planning and Management Tools, In: Barry Sadler, Ralf Aschemann, Jiri Dusik, Thomas Fischer, Maria Partidário and Rob Verheem, editor, *Handbook of Strategic Environmental Assessment*, London, Earthscan Publication, 2007, Pages: 1 – 704 (December 2010) ISBN:9781844073658.

28. Eales R. and SHEATE, W.R., Opportunities missed, and challenges to come? *Town and Country Planning,* 2010, 79 (3):138-143.

29. SHEATE WR, Eales R, Vaizgelaite I, *Appraisals of Sustainability and the New National Policy Statements: Opportunities Missed and Challenges to Come?* RSPB/WWF, 2010.

30. Phillips, P and SHEATE, W. R. (2010), The Scottish SEA Pathfinder Project: Practical Implementation and recommendations for good-practice, *The Environmentalist,* 104: 9-22 (September 2010).

31. SHEATE, W R, and Partidário, M R (2010), Strategic approaches and assessment techniques: potential for knowledge brokerage towards sustainability, *Environmental Impact Assessment Review* Vol: 30:278-288.

32. Zhou, K. and SHEATE, W. R. (2009), Comparative analysis of SEA legal requirements and institutional structure in China (Mainland), Canada and the UK (England), *Journal of Environmental Assessment Policy and Management* 11 (4): 387-426 (Special Issue on SEA in China).

33. Madeira, N, Phillips, P and SHEATE, W. R (2009), Final Report to the Scottish Government, *SEA Pathfinder Project Stage 1: Research,* (April 2009) (summary report)

34. Partidário MR, SHEATE, W R, Bina O, Byron H, Augusto B. (2009), Sustainability assessment for agriculture scenarios in Europe's mountain areas: lessons from six study areas, *Environmental Management,* 2009, 43: 144 - 165.

35. SHEATE, W R, Partidário, M R, Byron, H, Bina, O and Bennett, S, (2008) Sustainability Assessment of Future Scenarios: Methodology and Application to Mountain Areas of Europe, *Environmental Management*, 41 (2): 282-299 (DOI:- 10.1007/s00267-007-9051-9).

36. SHEATE, W R, Eales, R, Daly, E, Murdoch, A, and Hill, C (2008), Case study to develop tools and methodologies to deliver an ecosystem-based approach: Thames Gateway Green Grids, Final report NR0109, London, Publisher: Defra, 2008.

37. Twigger-Ross, C, Tapsell, S, Fernández-Bilbao, A, Warburton, D, SHEATE, W, Davoudi, S, Fielding, J (2008) *Supporting the development of a Social Sciences Strategy for FCERM R&D: Social Science within FCERM Research: Practice and Future Prospects*. Defra R&D Technical Report FD2604/TR, available at http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=14735&FromSearch=Y&Publisher=1&SearchText=FD2604&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

38. SHEATE, W. R. (2008), Strategic Environmental Assessment, in *New Oxford Companion to Law*, OUP (August 2008).

39. SHEATE, W.R and Kiely, A (2007), Causal chain analysis: making the link, *The Environmentalist*, Issue 51, pp 21-23 (October 2007).

40. SHEATE, W.R. and Bennett, S. (2007), *The Water Framework Directive, Assessment, Participation and Protected Areas: What are the Relationships?* Synthesis Report to the Irish Environmental Protection Agency, ERTDI Research Programme, Report No. 67 (October 2007, available at http://www.epa.ie/downloads/pubs/research/water/name,23575,en.html).

41. Bennett, S. and SHEATE, W. R. (2007), *The Water Framework Directive, Assessment, Participation and Protected Areas: What are the Relationships?* Final Report to the Irish Environmental Protection Agency, ERTDI Research Programme (October 2007, available at http://www.epa.ie/downloads/pubs/research/water/name,23576,en.html).

42. SHEATE, W, Zamparutti, T, Bennett, S and Rogeli, M (2007), Literature review and mega trends of driving forces of future environmental change, Final Report by Collingwood Environmental Planning and Milieu Ltd to the European Environment Agency (November 2007), available here.

43. Maxwell, D. and SHEATE, W. (2006), Enabling Sustainable Development through Sustainable Consumption and Production, *International Journal of Environment and Sustainable Development*, 5(3): 221 -239.

44. Maxwell, D., SHEATE, W. and van der Vorst, R. (2006) Functional and systems aspects of the sustainable product and service development approach for industry, *Journal of Cleaner Production*, 20:1 – 14.

45. SHEATE, W. R. (2006), Book Review: Environmental Assessment: The Regulation of Decision-Making, by Jane Holder, 2004, Oxford: Oxford University Press, 398 pp, *Journal of Environmental Law,* 18 (2): 326-328. (invited contribution).

46. SHEATE, W. R. and Leinster, T, (2005) SEA of Water Industry Plans and Programmes, *Water Law*, 16 (4):115-121.

47. SHEATE, W., Byron, H, Dagg, S and Cooper, L (2005), The Relationship between the EIA and SEA Directives, Final Report to the European Commission DG Environment, Contract No. ENV.G.4./ETU/2004/0020r, August 2005 (available at http://ec.europa.eu/environment/eia/pdf/final_report_0508.pdf).

48. Gu, L. and SHEATE, W. R. (2005), Institutional Challenges for EIA Implementation in China: a Case Study of Development versus Environmental Protection, *Environmental Management*, Vol. 36 (1), 125-142.

49. Gordon, D. J., Blaza, A and SHEATE, W. R. (2005), A Sustainability Risk Analysis of the Low Cost Airline Sector, *World Transport Policy and Practice*, 11 (1): 13-33.

50. Scrase, J. I. and SHEATE, W. R. (2004), Re-framing Flood Defence in England and Wales, *Environmental Values,* 14:113-137.

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52. Kaszewski, A.L. and SHEATE, W. R. (2004) Enhancing the Sustainability of Airport Developments, *Sustainable Development*, 12 (4), 183-199.

53. SHEATE, W. R. (2004), The SEA Directive 2001/42/EC: Reinvigorating Environmental Integration, *Environmental Law and Management* 16 (3), 119-124.

54. Adomokai, R and SHEATE, W. R. (2004), Community Participation and Environmental Decision-Making in the Niger Delta, *Environmental Impact Assessment Review*, 24, 495-518.

55. SHEATE, W.R., Byron, H.J. and Smith, S. P, (2004) Implementing the SEA Directive: Sectoral Challenges and Opportunities for the UK and EU, *European Environment,* Vol. 14 (2), 73-93.

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57. SHEATE, W.R. (2003), Changing Conceptions and Potential for Conflict in Environmental Assessment - Environmental Integration and Sustainable Development in the EU, *Environmental Policy and Law*, Vol. 33 (5): 219-230

58. SHEATE, W.R. (2003), EIA: There's Life in the Old Dog Yet (Invited commentary on "What's the Alternative? Impact Assessment Tools and Sustainable Planning" by John F Benson) *Impact Assessment and Project Appraisal,* Vol. 21 (4), 273-275.

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60. Eales, R., Smith, S., Twigger-Ross, C., SHEATE, W., Özdemiroglu, E., Fry, C. and Tomlinson, P. (2003), *Integrated Appraisal Methods*, R&D Technical Report E2-044/TR, Environment Agency of England and Wales: Bristol, available at http://publications.environment-agency.gov.uk/pdf/SE2-044-TR-e-e.pdf

61. Winterton, B. and SHEATE, W. (2003), Sustainability and Road User Charging (RUC) in UK Cities, *World Transport Policy and Practice*, Vol. 9 (4), 5-20.

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64. Cooper, L M and SHEATE, W R (2002), Cumulative Effects Assessment: A Review of UK Environmental Impact Statements, *Environmental Impact Assessment Review* Vol. 22 (4), 403-425.

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110. SHEATE, W R (1984), The EEC draft Directive on Environmental Assessment of Projects: its history, development and implications. MSc thesis, University of London.

Selected Invited Conference Papers and Lectures

1. SHEATE, W.R. and Partidario, M.R, What's the point of participation if not to enable knowledge-sharing and learning processes? Paper given at the **20th Annual International Sustainable Development Research Society (ISDRS) conference**, 18-20 June 2014, Trondheim Norway.

2. SHEATE, W.R. EIA and the Water Framework Directive, invited speaker at **Environment Impact Assessment Procedures in the EU** Seminar , Trier, Germany, 10-11 April 2014, Academy of European Law (ERA).

3. SHEATE, W.R. Streamlining SEA Processes, invited speaker at **2nd Kingsland Conference: The Strategic Environmental Assessment Directive: A Plan For Success?** held at King & Wood Mallesons SJ Berwin, London, 14 February 2014 (Centre of European Law, Kings College University of London/Francis Taylor Buildings).

4. Russel, D., Turnpenny, J. Bond, A., SHEATE, W., Jordan, A. and Adelle, C. - Embedding ex-ante policy appraisal at different governance levels and across policy domains: institutional barriers and enablers and lesson drawing, paper presented at the **International Conference on Public Policy**, Grenoble, France, 26-28 June 2013.

5. SHEATE, W. R. SEA in Practice – Making Assessment Count, Guest speaker at **Landmark Chambers Seminar SEA: Recent Developments,** 24 October 2012, London.

6. SHEATE, W.R., Exit and Voice: IA for Accountability & Sustainability, paper presented at **International Association for Impact Assessment IAIA12 Energy Future: The Role of Impact Assessment**, Porto, Portugal, 27 May - 1 June 2012.

7. Eales, R. and SHEATE, W.R, Challenges of Applying Policy Strategic Environmental Assessment in Europe, **International Association for Impact Assessment (IAIA11)**, **SEA Implementation and Practice: Making an Impact?** Prague, Czech Republic, 21-23 September 2011.

8. Eales, R. Baker, J. and SHEATE W.R, Integrating a Resilience Approach into Strategic Environmental Assessment, **International Association for Impact Assessment (IAIA11)**, **SEA Implementation and Practice: Making an Impact?** Prague, Czech Republic, 21-23 September 2011.

9. SHEATE, W. R., Strategic Environmental Assessment: Lessons from Practice, invited paper

given to **Royal Town Planning Institute (RTPI) Conference: Planning and the Natural Environment,** 16 June 2010, London.

10. SHEATE, W. R. , Daly, E. and Zamparutti, T, **Embedding futures thinking in environmental policy making,** poster presentation **to International Association for Impact Assessment annual conference (IAIA 10),** Geneva, Switzerland, 8-11 April 2010.

11. Sheate, W.R., Twigger-Ross, C., Luscombe, P. and Cheater, S., The Mersey gateway: SIA in Practice, paper given to **International Association for Impact Assessment annual conference (IAIA 10),** Geneva, Switzerland, 8-11 April 2010.

12. SHEATE, W.R., Invited Panel Member – Deep Uncertainties Session, **International Association for Impact Assessment annual conference (IAIA 10),** Geneva, Switzerland, 8-11 April 2010.

13. SHEATE, W.R. and Partidario, M.R., Strategic approaches and assessment techniques – potential for knowledge brokerage towards sustainability, Conference proceedings of the **15th Annual International Sustainable Development Research (ISDR) conference**, Utrecht Netherlands, 5-7 July 2009 (available at www.isdrs.org), 2009.

14. Partidario, M.R. and SHEATE, W.R. The Potential Role of SEA and SA as knowledge brokers for sustainability, paper given to **International Association for Impact Assessment annual conference (IAIA 09),** Accra, Ghana, 17-22 May 2009, 2009.

15. SHEATE, W.R (2008), Invited paper : Outils, Techniques et Approches pour L'évaluation de Durabilité: Pratique contre la Théorie, École thématique **"Évaluation de la Durabilité",** Cargèse, Corsica, 19-24 October, 2008 (in French).

16. SHEATE, W. R. (2008), EIA and SEA: their inter-relationship and role as instruments for sustainable development, invited speaker to the Ministerial/High Level Segment - "The Convention 10 years after its entry into force: future directions" - of the **4th Meeting of the Parties of the UNECE Espoo Convention on Environmental Impact Assessment in a Transboundary Context,** 20 May 2008, Bucharest, Romania.

17. SHEATE, W. R. (2007), Climate Change Adaptation - Strategy and Integrated Appraisal in London, Invited paper given to **Changing Climates for Environmental Assessment,** IAIA – UK-Ireland Branch event (with IEMA), University of Manchester, 24 October 2007.

18. SHEATE, W.R. (2007), Invited paper: De l'évaluation environnementale á l'évaluation de la durabilité, **Atelier "évaluation de la durabilité", Centre national de la recherche scientifique (CNRS), Paris**, 13 June 2007 (in French).

19. SHEATE, W.R. (2007), The Water Framework Directive and SEA: The WAPPA project (Ireland) - The Water Framework Directive, Assessment, Participation and Protected Areas: What are the Relationships?, paper given on behalf of the Irish Government to **EU Member State Workshop on WFD and SEA**, SOAS, London, 19 April 2007

20. SHEATE, W R, and Madeira, N (2006), Sustainability through Strategic Environmental Assessment (SEA) – a key driver to stimulating institutional and cultural change? Paper given to the **Sustainable Development Research Centre (SDRC)** Conference, Sustainability – Creating the Culture, 15 November 2006, Perth, Scotland.

21. SHEATE, W R, Byron, H, Bennett, S and Cooper, L (2006), The Relationship Between the EIA and SEA Directives, paper presented at **the International Association for Impact Assessment (IAIA06)** annual conference, on Power, Poverty and Sustainability, Stavanger, Norway, 23-26 May 2006

22. Bennet, S and SHEATE, W R (2006), *The Water Framework Directive, assessment, participation and protected areas: what are the relationships?* Paper presented at **the International Association for Impact Assessment (IAIA06)** annual conference, on Power, Poverty and Sustainability, Stavanger, Norway, 23-26 May 2006

23. SHEATE, W R, Partidário, M R, Byron, H, and Bina, O (2006), *Sustainability Assessment: Lessons from the EU BioScene project,* paper presented at **the International Association for Impact Assessment (IAIA06)** annual conference, on Power, Poverty and Sustainability, Stavanger, Norway, 23-26 May 2006

24. SHEATE, W R (2006), EIA, SEA and Sustainability: From there to here to where? Seminar given to the Research Forum, Department of Civic Design, **University of Liverpool**, 4 May 2006

25. SHEATE, W R (2006), *Strategic Environmental Assessment and Environmental Impact Assessment: The Interrelationship between the SEA and the EIA Directives,* seminar given to the **Planning and Environment Bar Association**, The Court Room, Lincoln's Inn, 16 February 2006

26. SHEATE, W R (2005) *Strategic Environmental Assessment of Water Industry Plans and Programme,* paper presented at **Water, Water Everywhere……** conference organised by 2 Harcourt Buildings Chambers, English Heritage Lecture Theatre, Savile Row, London, 3 October 2005

27. SHEATE, W R, Partidário, M R, Byron, H, Bina, O and Dagg, S (2005), *Sustainability Assessment of Future Scenarios: Methodology and Application to Mountain Areas of Europe*, paper presented at **IAIA-SEA Prague: International Experience and Perspectives in SEA**, Prague, Czech Republic, 26-30 September 2005

28. SHEATE, W R, Partidário, M R, Byron, H, Bina, O and Dagg, S (2005) *BioScene: The Development and Application of a Sustainability Assessment Methodology,* paper given at **Biodiversity Conservation and Sustainable Development in Mountain Areas of Europe: The Challenge of Interdisciplinary Research** conference, Ioannina, Greece, 20-24 September 2005

29. Partidário, M R, SHEATE, W R, Bina, O, and Byron, H (2005), *Sustainability Assessment – Cross-country analysis in Bioscene*, paper given at **Biodiversity Conservation and Sustainable Development in Mountain Areas of Europe: The Challenge of Interdisciplinary Research** conference, Ioannina, Greece, 20-24 September 2005

30. SHEATE, W R, Partidário, M R, Byron, H and Bina, O (2005) Sustainability Assessment of Scenarios for Agriculture Development and Biodiversity Conservation in Mountain Areas, paper given at **11th Annual International Sustainable Development Research Conference**, Helsinki, Finland 6-8 June 2005 in the *Transdisciplinary Case Study Research Symposium*

31. Partidário, M R, SHEATE, W R, Bina, O, and Byron, H (2005), Sustainability Assessment of Scenarios for Agriculture Development and Biodiversity Conservation in Mountain Areas, paper presented at IAIA'05, *Ethics and Quality in Impact Assessment*, **International Association for Impact Assessment,** 31 May - 3 June 2005,Hyatt Regency Cambridge Hotel in Boston, Massachusetts, USA.

32. SHEATE, W R (2005*) SEA challenges, perspectives and potential*, Keynote speech given to **Strategic Environmental Assessment, Water and Planning: Getting good value - challenges for application and delivery, CIWEM conference** held on 11 May 2005, at SOAS, London.

33. SHEATE, W R (2003), The SEA Directive: A Much-Need Boost for Environmental Integration, invited paper given to Conference "*The State of Environmental Assessment: Law, Custom and Practice*" organised by the Centre for Law and the Environment, **University College London**, Senate House, 8 December 2004.

34. SHEATE, W R (2003), Invited panel member of "Meet the Editors" workshop of EIA journal editors at the **International Association for Impact Assessment Annual Conference**, Marrakech, Morocco, June 2003.

35. SHEATE, W R (2003), Chair and Convenor of three workshops on *Linking Impact Assessment and Management Tools*, at the **International Association for Impact Assessment Annual**

Conference, Marrakech, Morocco, June 2003.

36. SHEATE, W R (2002), Invited panel member of "Meet the Editors" workshop of EIA journal editors at the **International Association for Impact Assessment Annual Conference**, The Hague, Netherlands, June 2002

37. SHEATE, W R (2002), Chair and Convenor of two workshops on *Linking Impact Assessment and Management Tools*, at the **International Association for Impact Assessment Annual Conference**, The Hague, Netherlands, June 2002.

38. SHEATE, W R (2001), SEA and the Integration of the Environment into Strategic Decision-Making, invited presentation of research findings **to EU EIA/SEA Experts seminar**, Vaxholm, Sweden, 29 June 2001.

39. SHEATE, W R (2001), SEA and the Integration of the Environment into Strategic Decision-Making, seminar presentation at **University of Manchester School of Planning and Landscape**, 22 May 2001.

40. SHEATE, W R (2000), *EIA, SEA and Environmental Planning*, invited panel speaker at **Royal Commission on Environmental Pollution Seminar on Environmental Planning**, Institute of Materials, London, 3 February 2000.

41. SHEATE, W R (1999), Chair and Convenor of two workshops on *Assessment of Environmental Effects: Making the Links Between Tools*, at the **International Association for Impact Assessment Annual Conference**, Glasgow, June 1999.

42. SHEATE, W R (1998), *Strategic environmental assessment and transport*, paper given to CESAM/Nordic-European Research Course, **Land Use and Nature Protection**, Aarhus, Denmark, 27 August 1998.

43. SHEATE, W R and Byron, H, (1998) *Treatment of biodiversity issues in road environmental impact assessments*, **Linnean Society Conference on Wildlife and Roads: the ecological impact**, Linnean Society, London 11-12 March 1998 (forthcoming proceedings).

44. SHEATE, W R (1997), *Transport Policy: Integrating Science, Technology and Perceptions*, paper given to SCOPE conference on the **Effective Use of the Sciences in Sustainable Development**, Royal Society, London, 21 February 1997.

45. SHEATE, W R (1995) *Evolution of EA in the UK*, paper given to **CIRIA Construction Industry Environmental Forum Workshop, Environmental Assessment - Policy and Practice**, 12 January 1995, Canary Wharf, London

46. SHEATE, W R (1995) *The Participation of the Public and Non-Governmental Organisations in the EIA Process: Opportunities and Obstacles*, paper given to the **15th Annual Meeting of the International Association for Impact Assessment (IAIA) Impact Assessments: Involving People in the Management of Change towards a Sustainable Future**, 26-30 June, Elangeni Hotel, Durban, South Africa.

47. SHEATE, W R and Atkinson, N R (1995) *Public Participation in Environmental Procedures*, paper given to the **Annual FIELD/Cameron May Summer School on Environmental Law**, The Regus Conference Centre, London WC2, 3-7 July.

48. SHEATE, W R (1995) *Concrete and Tyres: Transport Impacts on the Physical Environment*, paper given to the **Chartered Institution of Water and Environmental Management (CIWEM) Transport and the Environment - the End of the Road? Options for sustainable policy and practice**, Church House Conference Centre, Westminister, London.

49. SHEATE W R (1995) *Pressures: Road Transport and the Environment*, paper given to the **Institute of Road Transport Engineers 26th Annual Conference and Display**, 18 May, Telford International Centre, Telford.

50. SHEATE, W R (1995) *The Purpose and Effect of Strategic Environmental Assessment: The Future*, paper given to **Airfields Environment Federation conference Environmental Assessment of Airports** - Current Issues, 12 October 1995, Royal Society of Arts, London.

51. SHEATE, W R (1995) *Amending the EC Directive (85/337/EEC) on Environmental Impact Assessment*, paper given to **Cameron May/Berrymans Conference Construction Law and the Environment**, 15 November 1995 at the Royal Society of Arts, London.

52. SHEATE, W R (1995) *Why is SEA Desirable for Local Authorities?* Paper given to the **Green Alliance Conference Strategic Environmental Assessment (SEA) in Local Authorities**, 23 November 1995, Baden-Powell House, London

53. SHEATE, W R (1994) *Improving Public Participation in EIA*, paper given to conference organised by **Manchester University EIA Centre on Improving the Role of Environmental Impact Assessment in Achieving Sustainable Development**, 14 April 1994.

54. SHEATE, W R (1994) *Strategic Environmental Assessment and Public Participation in the European Union*, paper given to the **14th Annual Meeting of the International Association for Impact Assessment (IAIA) 25 years of Impact Assessment: Looking Back and Projecting the Future**, Quebec City, Canada, 14-18 June 1994

55. SHEATE, W R (1994) *Managing Resources in a World of Sustainable Development: Breathing New Life into EIA*, paper to **Institution of Water and Environmental Management (IWEM) Training Conference, Sustainability in Engineering Practice**, The Wiltshire Hotel, Swindon, 12 October 1994.

56. SHEATE, W R (1994) *Strategic Environmental Assessment*, paper given to **National Rivers Authority Seminar for Environmental Assessment Specialists and Senior Managers**, Coventry Hilton, 13 October 1994.

57. SHEATE, W R and Cerny, R J (1993) *Legislating for EIA: Learning the Lessons*, paper given to the **13th Annual Meeting of the International Association for Impact Assessment (IAIA) Development and the Environment**, Shanghai, China, 11-15 June 1993.

58. SHEATE, W R (1993) *Assessing the benefits of road and rail: a critique*, paper given to **Hertfordshire Conservation Society's Regional Transport Strategy Conference**, Blakemore Hotel, Little Wymondley, 16 July 1993.

59. SHEATE, W R (1992) *How effective are environmental assessments in protecting the rural environment*, paper given to **Aston University Conference on Environmental Assessment**, at Aston University, Birmingham, 12 March 1992, UK

60. SHEATE, W R (1992) *Environmental Assessment: Scoping, Consultation and Co-ordination*, paper given to **Agricultural Development and Advisory Service (ADAS) conference on Environmental Assessment: Help or Hindrance**, at Forte Posthouse Hotel, Crick, Northamptonshire, 9 April 1992.

61. SHEATE, W R (1992) *Environmental Assessment in the European Community*, paper given to **British Public Works Association (BPWA) Conference on Europe - New Challenges**, at National Agricultural Centre, Stoneleigh, Warwickshire, 8 October 1992.

62. SHEATE, W R (1992*) Water and Wetlands - the need for environmental monitoring and reporting in the UK*, paper given to **Broads Authority/Heritage Resources Centre/UEA workshop Assessing and Monitoring Change in Wetland Parks and Protected Areas**, Norfolk Mead Hotel, Coltishall, Norfolk, 9 - 13 October 1992.

63. SHEATE, W R (1992) *An NGO perspective on the benefits and performance of Environmental Assessment in Britain*, paper given to the **British Association of Nature Conservationists/University College London Conference Environmental Assessment: Green Progress or Greenwash?**, University College, London, 11 December 1992.

64. SHEATE, W R (1991) *Environmental Pressures on Water Users*, paper given to **Confederation of British Industry (CBI) Conference on Water: Improving Efficiency and Managing Costs**, CBI, Centre Point, London, 3 July 1991.

65. SHEATE, W R (1991. *Environmental Assessment Procedures: the Environmentalist's View*, paper given to **Royal Town Planning Institute (RTPI) conference on Explaining Environmental Assessments**, at RTPI, Portland Place, London, 1 November 1991.

66. SHEATE, W R (1990) *Environmental Protection Bill: Pollution Control*, paper given at Seminar: **'Green Legislation 1990', 4 April 1990, Mersey Basin Campaign**, Manchester

67. SHEATE, W R (1990) *A Perspective from England*, paper given to conference on **The Countryside Council for Wales, Council for the Protection of Rural Wales (CPRW) Annual Conference**, 6/7 April 1990, Aberystwyth.

68. SHEATE, W R (1990) *Regulating the Water Environment: The Next Steps*, paper to **Conference on Environmental Law of the European Communities - A Practical Approach**, Durham, 20/21 July 1990

69. SHEATE, W R (1990) *Public Participation: The Key to Effective Environmental Assessment*, paper given to **Conference on Environmental Assessment: Theory and Practice**, Café Royal, London, 8/9 November 1990, organised by IBC Legal and Technical Services Ltd.

Research Students supervised – 1995-2013

Diploma of Imperial College (DIC, one year by research)

- **Gu Lixin** (1995-1996) British Council scholarship: *The overlaps and interactions of environmental impact assessment, risk assessment and environmental auditing : a case analysis of the Channel Tunnel and Sizewell B Nuclear Power Station.*

PhD students

- **Juan Romanillos Palerm** (1995-1998) Mexican Govt studentship: *Public participation in environmental impact assessment, an empirical-theoretical analysis framework*
- **Jeremy Richardson** (1995-1999) ESRC/CPRE CASE Studentship: *Strategic Environmental Assessment of Trunk Road Plans and Programmes*
- **Helen Byron** (1996-2000) ESRC/RSPB CASE studentship: *Treatment of biodiversity issues in environmental impact assessments of road schemes*
- **Steven Smith** (1998-2002) ESRC Studentship: *Sustainability Appraisal and the SEA Directive in English Regional Planning*
- **Gu Lixin** (1997-2001) *Environmental Management in Multi-National Companies in China and the UK*
- **Jillian Anable** (1997-2002) ESRC/National Trust CASE Studentship: *Mobility Management in the Leisure Industry*
- **Konstantinos Evangelinos** (1998-2003) *Environmental Management Systems Standards in Corporate Decisions and Policy Making*
- **Lourdes Cooper** (1999-2004) *Cumulative Effects Assessment, Strategic Planning and Urban Regeneration: the Case of the Thames Gateway*
- **Juliette McDonald** (1999-2003) ESRC/Camden Council CASE Studentship: *Development and Assessment of a Public Participatory Framework for Integration of Computer Modelling in LAQM Decision-Making*
- **Dorothy Maxwell** (2000-2004) *Sustainable Product and Service Development in Manufacturing Industry*
- **Ivan Scrase** (2000-2006) ESRC/Environment Agency CASE Studentship: *Development of Conceptual Models and Tools for the Strategic Appraisal of Policies, Plans and Programmes*
- **Kaiyi Zhou** (2005-9) *SEA and Provincial Level Expressway Programme Planning: an Application Framework and Indicator System for China*
- **Alison Wadmore** (p/t) (2004-) *Risk Assessment of Poaching Incentives and Deterrents in Tigers*
- **Uzoma Ojike** (2006-2012) *Combining Tools and Techniques for embedding an ecosystems approach in spatial planning*
- **Shahryar Mohammadrezaie Omran** (2010-) *Transition Management Approach to Low Carbon Transportation in Iran.*
- **Megan Quinlan** (p/t) (2011-) *Mosquitoes and risk management*

Research degrees examined

MRes examined:-

- University of East Anglia – Sheryl French (MRes), 1998 (*The influence of environmental impact assessment and strategic environmental assessment in decision making*)
- University College Dublin - Damien Keneghan (MRes), 2013 *(A review of worldwide best practice in the assessment of biological control of invasive alien species: facilitating the development of an Irish framework)*

PhDs examined:-

- Oxford Brookes University – Caroline Bellanger, 1999 (*Divergent practice in a converging system? The example of environmental impact assessment in the European Union*)
- Manchester University – Jeremy Carter, 2004 (*The effect of strategic environmental assessment on the preparation of structure plans*)
- Imperial College London – Fernando Farias, October 2005 (*Air pollution exposure and integrated assessment modelling around London's Heathrow airport*)
- Manchester University – Andries van der Walt, November 2005 (*Consideration of cumulative effects in environmental assessment : South African experience in an international context*)
- University of Surrey – Kalliope Pediaditi, October 2006 (*Evaluating the sustainability of Brownfield redevelopment projects: the redevelopment assessment framework (RAF*).
- University of Liverpool - Paola Gazzola, December 2006 (*Adapting Strategic Environmental Assessment for Integration in Different Planning Systems*)
- University of Cardiff - Dilek Unalan, August 2007 (*Environmental Policy Adoption in the EU Context: Adoption of the EU SEA Directive in Turkey*)
- Imperial College London - James Haselip, October 2007 (*Electricity Market Reform in Argentina: Pre And Post Crisis Policies, Institutions And Ideas*)
- Oxford Brookes University – Cailing Hu, April 2008 (*The Implementation of water pollution control at local level: A comparative study in China and England*)
- Imperial College London – Nia Davies, November 2008 (*Advancing comparative policy evaluation techniques: A case study of British climate change policies*)
- University of Manchester – Cassandra Wesolowski, December 2008 (*The optimum role of tiered environmental assessments relating to long-term radioactive waste management in the UK*)
- Imperial College London - Caroline Howe, September 2009 (*The Role of Education as a Tool for Environmental Conservation and Sustainable Development)*
- Oxford Brookes University – Joe Weston (PhD by publication, December 2009) (*Environmental Impact Assessment: A Critical Theory Analysis*)
- University of Liverpool – Paula Posas (December 2009) (*SEA and climate change*)
- University of Manchester – Anna Gilchrist (July 2010) (*Climate Change, Species Range Expansion and the Institutional Response*).
- Imperial College London – Sukaina Al Wasity (March 2011) *(Aviation Air Pollution Studies in the Emirate of Abu Dhabi).*
- Oxford Brookes University – Katherine Drayson (April 2013) *(An Evaluation of Ecological Impact Assessment in England).*

- University of Manchester – Samuel Hayes (December 2013) *(Strategic Assessment in England and Scotland: Analysing the contribution to sustainability).*

- Imperial College London - Ricardo de Albuquerque Martins (May 2014) *A Wood Fuel Energy Systems Metamodel: A Novel Approach to Participatory Conceptual Design – the Case of Mozambique*.

ANNEX 6

Golder Associates, Inc., "The Requirements of Impact Assessment for Large-Scale Road Construction Project in Costa Rica Along the San Juan River, Nicaragua," July 2014

REPORT

THE REQUIREMENTS OF IMPACT ASSESSMENT FOR LARGE-SCALE ROAD CONSTRUCTION PROJECT IN COSTA RICA ALONG THE SAN JUAN RIVER, NICARAGUA

Prepared for: Republic of Nicaragua

Submitted By: Golder Associates Inc.
6026 NW 1st Place
Gainesville, FL 32607 USA

July 2014

Project No. 1402647

Table of Contents

1.0 EXECUTIVE SUMMARY

As engineers and scientists who conduct Environmental Impact Assessments (EIAs) for infrastructure projects throughout the world, including in Latin America, we were asked by the Government of Nicaragua to evaluate the EIA process, or the lack thereof, undertaken by Costa Rica for the construction of Route 1856, a highway project located in northern Costa Rica in close proximity to Nicaragua's San Juan River. Based on our professional experience, we have no doubt that the Route 1856 project required an EIA and that the failure to carry out this assessment has resulted in significant and predictable impacts, including to Nicaragua.

EIA is an evaluation process that seeks to identify, prior to the commencement of a project, what will be the project's environmental and social impacts, and to identify ways in which those impacts can be avoided, minimized or mitigated. Whether a project requires an EIA is determined by a "screening" process that determines if the project is likely to cause significant environmental or social impacts.

Costa Rica did not screen the Route 1856 project. Had a proper screening exercise been carried out, it would have determined that the project required an EIA. Not only does Costa Rican law require EIA for highway projects, including for roads that are much smaller than Route 1856, the project clearly was likely to have significant impacts. This is because Route 1856 was sited in an area of very high precipitation and erodible soils, making the large-scale erosion of sediment a significant risk. The road's close proximity to numerous bodies of water, including the San Juan River and tributaries to it, make the risk of sediment contamination to the river from erosion a particular concern. Other significant risks that would have been identified had Costa Rica screened Route 1856 include likely impacts to the area's protected areas, biodiversity and primary forests.

A proper EIA for Route 1856 should have characterized the project's risks and likely impacts by evaluating the biophysical and social components, including among other things hydrogeology, hydrology, surface and ground water quality, geology and geomorphology, soil, natural and industrial hazards, aquatic and terrestrial ecology, biodiversity, protected areas, human and ecological health, and visual aesthetics. This should have included, at a minimum, a clear description of the project, including the identification and evaluation of its biophysical and social issues and related risks, and analysis of alternative sites for the project. It also should have included the collection of pre-project baseline data so that possible project-related impacts could be compared to pre-existing conditions. Once baseline data had been collected, Costa Rica should have superimposed Route 1856 onto the baseline, in order to predict where, how and how much the project was likely to impact baseline conditions. Through this process, Costa Rica should have identified required mitigation measures and prepared an Environmental Management Plan to address, among other things, impacts from eroding sediment into water bodies, including the San Juan River.

Had Costa Rica undertaken even a limited EIA, it would have determined that Route 1856 posed significant risks, including to Nicaragua's San Juan River, due to the likelihood that large quantities of sediment would erode from the area of the road and enter the river, either directly or through tributaries. This was entirely predictable, given the failure to design the road or to comply with widely-accepted roadway engineering standards, including with respect to the construction of stream crossings, and the failure to compact side-cast fill material. Large-scale erosion of sediment into the San Juan River was also foreseeable in light of the road's very close proximity to the river, and the fact that it was built on steep topography with erodible soils in areas characterized by high levels of precipitation. These predictable outcomes have materialized, as we observed first-hand from boat and helicopter in May 2014. In our view, the large size sediment deltas that have developed in the San Juan River would not be acceptable in any environmental regulatory regime of which we are aware.

The "Environmental Diagnostic Assessment" (EDA) produced for Costa Rica in November 2013, well after much of Route 1856 had been constructed, does not redress the problems created by Costa Rica's failure to carry out an EIA. An EIA is intended to identify impacts prior to a project being carried out, so that the predicted impacts can be prevented, minimized, compensated and/or mitigated. The objective of an EDA, on the other hand, is to identify impacts after they have occurred. Accordingly, many of the recommendations made in the EDA with respect to the design and construction of Route 1856 have come too late.

The EDA also contains fundamental flaws that render its conclusions with respect to anticipated impacts from Route 1856, especially to Nicaragua, untenable. It arbitrarily defined the scope of the road's impact as a 1000 m strip extending to the south from the right bank of the San Juan River. As a result, the EDA's scope did not include road-related works carried out elsewhere, including the project's extensive network of access roads. Even more seriously, by defining its coverage as the belt of land located 1000 m south of the San Juan's right bank, it excluded from consideration Nicaraguan territory, including the river itself. Other flaws include the EDA's characterization of ecological impacts in a manner that appears to be quantitative but which, in fact, is subjective and susceptible to manipulation, and its artificial reduction of the significance of impacts, including sedimentation of water bodies, by improperly considering them solely in light of the overall roadway project, rather than in their local context, as is the proper approach.

In sum, we conclude that Costa Rica should have carried out an EIA for Route 1856, and that its failure to do so has resulted in significant impacts to Nicaragua, including most prominently in the form of sedimentation of the San Juan River, which would not have occurred, or would have been much reduced, had an impact assessment been conducted. We therefore recommend that:

- the Road not be allowed to persist in its current unprotected state;
- the Road not be used for the transport of hazardous materials;
- meaningful erosion control needs to be implemented;
- mitigation works need to be undertaken in a way that does not cause additional harm; and
- new development projects that can impact Nicaragua, now possible because of the Road, also be preceded by proper planning and EIA with Nicaragua considered as an interested stakeholder.

2.0 AUTHOR QUALIFICATIONS

This report has been prepared by Mr. Benny Susi, P.E., Principal and Practice Leader with the International Environmental and Social Due Diligence Services practice at Golder Associates Inc. (Golder), a global engineering and environmental consulting firm, and by Mr. Rene Lozada, MS, Environmental ESIA Specialist, at Golder.

Mr. Susi has managed, directed, or been principal lead on numerous Environmental and Social Impact Assessments (ESIAs). He is a Principal and Senior Engineer and Project Manager with more than 30 years of experience in domestic and international inter-disciplinary environmental projects, including projects in the mining, oil and gas, infrastructure, power plant, and waste management sectors. The work has involved environmental impact studies, compliance audits, protection of air resources, environmental permitting, and transactional audits.

Mr. Susi has directed, managed, or been lead engineer on projects involving all aspects of industrial development throughout the U.S. and in numerous countries. He has been the project manager or project director on ESIAs for: power plants in Panama and the Dominican Republic; pipelines in Bolivia and Nicaragua; LNG facilities in Mexico, the Dominican Republic, and Peru; mining projects in the Dominican Republic and Mexico; and a large industrial petrochemical project in Peru. He has also served as environmental engineer for a consortium of lenders for the Canatarell Oil Field re-gasification project in Mexico.

Mr. Susi graduated from the University of Florida in 1979 with a M.E. in Civil Engineering, after having acquired his B.S. in Civil Engineering from the same institution in 1977. Mr. Susi is a member of the American Society of Civil Engineers and Tau Beta Pi Honorary Engineering Society.

Mr. Lozada is a Senior Environmental Specialist resident in Bogotá, Colombia. He has 25 years of experience in conducting and managing Environmental and Social Impact Assessments, Environmental Management Plans, Contingency Plans, and Phase I EHS Due Diligence and Audits on a range of development projects throughout Central America, the Caribbean and South America. His focus has been on work related to the transportation, oil & gas, mining, and industry sectors. René blends a successful environmental consultancy with first-hand regulatory and institutional experience, having worked with a Regional Environmental Authority and with the United Nations Development Program in Colombia before developing experience in international consultancy.

Mr. Susi and Mr. Lozada have worked together for the last 15 years on international ESIAs in many Latin American countries such as Mexico, Bolivia, Nicaragua, Peru, Colombia, Chile, the Dominican Republic, and Panama. As managers and directors of ESIA projects, they have been responsible for developing the overall scope and strategy of ESIAs, including the various phases such as: screening; scoping (planning); environmental and social baseline strategy; baseline data collection and work plans focusing on the issues identified during the planning/scoping phase; impact assessment; and Environmental and Social Management Plans (ESMPs) and monitoring plans. As the overall leaders of such projects, they have directed technical staffs comprised of many specialists in order to meet the objectives of developing ESIA processes.

Resumes detailing the experience of the authors of this report are presented in Appendix 2.

3.0 INTRODUCTION

The documents reviewed by the authors of this report (hereafter referred to as “Golder”) include:

- Application of the Republic of Nicaragua Instituting Proceedings Against the Republic of Costa Rica (December 2011)
- Republic of Nicaragua Memorial (December 2012), including:
  - Annex 2: Costa Rican “Environmental Management Plan: Juan Rafael Mora Porras Road” (April 2012)
  - Annex 3: LANAMME Report (May 2012)
  - Annex 4: CFIA Report (June 2012)
- Counter-Memorial of Costa Rica including Annex 10, Environmental Diagnostic Assessment of the Ecological Component (November 2012)
- Costa Rica’s Decree 31849 of June 28, 2004
- Blanca Rios Touma, “Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua” (July 2014)
- Danny Hagans and Bill Weaver, “Evaluation of Erosion, Environmental Impacts and Road Repair Efforts at Selected Sites along Juan Rafael Mora Route 1856 in Costa Rica, Adjacent the Río San Juan, Nicaragua” (July 2014)

In addition, to gain first-hand understanding of the scope and impacts of the roadway project, Golder carried out a site visit to the affected area, including a helicopter flyover on May 2, 2014 (in Nicaraguan airspace) of the section of Route 1856 that runs parallel to the San Juan River, followed by site reconnaissance by boat along the San Juan River from May 2-4, 2014.

This remainder of this report consists of the following five sections:

- A discussion explaining that proper screening would have determined that the Route 1856 project required an EIA (Section 4);
- A discussion of what an EIA for Route 1856 should have included and why (Section 5);
- A description of the problems that have arisen as a result of the lack of pre-project EIA for Route 1856, based on the authors’ first-hand observation of the road works and review of relevant documentation (Section 6);
- An evaluation of Costa Rica’s December 2013 Environmental Diagnostic Assessment and an explanation of the reasons it is neither an EIA substitute nor an adequate post-construction audit (Section 7); and
- Conclusions and Recommendations (Section 8).

4.0 PROPER SCREENING WOULD HAVE DETERMINED THAT THE ROUTE 1856 PROJECT REQUIRED AN EIA.

Environmental and Social Impact Assessment (ESIA), sometimes referred to as Environmental Impact Assessment (EIA), is a well-recognized process aimed at developing a sustainable project and managing environmental and social performance throughout the project's life. Although ESIA is used in many countries as a permitting tool and an administrative process, it is fundamentally a planning process for project developers and a decision-making process for environmental authorities. It is also an important risk-management tool, as it identifies – prior to a particular project's development – the key issues that represent the potential to cause adverse environmental and social risks and impacts, and helps to ensure that those risks and impacts are properly accounted for.

A first and fundamental step that must take place before a project is developed is the determination of whether an EIA is required. This is known as "screening," and it entails determining whether and to what extent the project under review has the potential to cause significant impacts to the environment. If it does, then EIA is required. In our opinion, it is clear from an engineering and environmental perspective that the construction of Route 1856 required a comprehensive EIA. This is because the scope of the project and various site-specific factors combined to create a project with the capacity to cause substantial environmental impacts, including to Nicaragua. A screening process for this project, had it been undertaken by Costa Rica, would have determined that there was potential for significant adverse impacts that could have been avoided or minimized had the project been properly designed and well executed.

4.1 Costa Rica's EIA Regulation

As an initial matter, Costa Rican law would ordinarily require an EIA for the Route 1856 project. Decree 31849 of June 28, 2004 lists, in Annex 1, types of projects for which EIA is required. These include the following that apply to Route 1856: (a) construction of roads (as required under the Law of Administrating Contracts) (Annex 1, page 83); (b) state or private infrastructure projects of national interest (as required under the Forestry Law) (Annex 1, page 85); and (c) projects developed in wildlife refuge areas (as required under the Wildlife and Conservation Law) (Annex 1, page 82). Further, Annex 2 lists, in Category A, additional projects that require full EIA as a condition for obtaining a license for the project (Annex 2, p. 31). These include projects to construct national roads that are longer than 5 km and provincial roads that are longer than 10 km (Annex 2, p. 105). Regardless of whether Route 1856 is considered to be national or provincial, a full EIA is required by the EIA regulation since the road is much longer that these distances.

4.2 Possibility of Significant Adverse Impacts

Proper screening of the project, had it been undertaken, would also have determined that EIA for Route 1856 was required because the road has the potential to cause significant impacts, including to

Nicaragua, given such factors as the magnitude of the works, the sensitive environmental setting into which the project was to be introduced, and its proximity to the San Juan River.

4.2.1 Magnitude of the Project

The fact that the project extends for 160 km underscores the potential for significant impacts. In fact, the size of the project alone, which entails significant disturbance, is sufficient to conclude there is a likelihood of significant impacts.

4.2.2 Physical Realities

Screening of the Route 1856 project would have identified two important facts that indicate it is likely to have significant impacts. Not only is the project located in an area with a very high amount of rainfall (the third highest precipitation in Costa Rica[1]), it contains the Ultisol class of soil that represents the oldest and most weathered soils (EDA pg. 35). The combination of high precipitation and weathered (erodible) soils can be expected to lead to erosion. If not properly minimized and controlled, this has a high likelihood of causing the instability of constructed works and sedimentation in nearby bodies of water. In addition, the project area is subject to climatic conditions that include natural hazards, such as tropical storms and hurricanes (EDA pg. 35), which are likely to cause a greater degree of impacts associated with the erodible and exposed soils.

The risk posed by these factors is accentuated by the fact that Route 1856 is sited in very close proximity to Nicaragua's San Juan River, as well as to "numerous rivers of different dimensions … channels and creeks" (EDA pg. 55, also pgs. 36-37, 45). The presence of these bodies of water increases the likelihood of significant impacts to Nicaragua because many of them provide mechanisms for impacts to the San Juan River, to which they ultimately make their way. As the EDA acknowledges, seven of Costa Rica's "important hydrographic watersheds" empty into the San Juan, including the San Carlos and the Sarapiqui (EDA pg. 36), as well as smaller streams (EDA pg. 63). In the upriver section of Route 1856 above the San Carlos River, the EDA states that "28 tributary streams were identified that empty into the San Juan River" (EDA pg. 69).

Screening of Route 1856 would also have identified that the bodies of water in the project's area of influence are important to biodiversity and serve as habitat for species, some of which are endemic (only existing in these locations). For example, "[a]long the path of Route 1856 can be found complexly related wetlands associated with the lower watershed of the San Juan River," whose vegetation is "very valuable" due to its unique species composition, and which are "the habitat of fish and mammals such as the 'gaspar' (*Atractosteus tropicus*) and the Manatee or Sea Cow (*Trichechus*

[1] The EDA provides varying and inconsistent precipitation data but they all qualify as high annual averages: 1500-3500 mm (EDA, pg. 20), over 3200 mm (EDA pg. 35), 2300-4400 mm (EDA pg. 36), 2300-2800 mm (EDA pg. 42).

manatus), both of them endangered species" (EDA pg. 59). A section of the EDA is dedicated to endemic species of aquatic fauna (fish, mammals, reptiles and crustaceans) known to exist in the study area with reduced or threatened populations (EDA pgs. 106-108). The EDA warns of the possibility of disturbance or pollution of these aquatic habitats, observing: "The presence of endangered or highly threatened species in the study area is a condition that justifies protecting the riparian ecosystems" (EDA pg. 106).

More broadly, the EDA provides substantial information on the many threatened terrestrial and aquatic animal species present in the project's area of influence (EDA pgs. 62-63, 106-108), characterizing it as "a refuge for endangered species" (EDA pg. 64). It states:

> "The importance of the northern territory of Costa Rica, in addition to the presence of wetlands of high biological value, it contains the last remnant of very humid tropical forest where the mountain almond tree (*Dipteryx panamensis*) is a dominant species. It is also home to numerous threatened species, among them the emblem species: jaguar (*Panthera Onca*), the sea cow (*Trichechus manatus*) and the Great Green Macaw,[2] a species that is highly dependent on the almond tree as a source of nourishment and substratum for nesting." (EDA pg. 39)

A road project carried out in these areas inevitably risks causing significant impacts, including in Nicaragua. Not only can construction and use of the road destroy or damage areas of sensitive forest, the effects of such damage are likely to be felt within the broader ecosystem. In the case of Route 1856, the forest in Northern Costa Rica "is the life zone that provides the main connecting habitat between the southern part of the Atlantic watershed of Nicaragua and the Central Volcanic Range of Costa Rica" (EDA pg. 42). A connecting habitat, or wildlife corridor, is a specially designated habitat that connects wildlife populations by allowing for continuous free movement of species and continuity of plant communities, separated from human activities or structures. This connection allows an exchange of individuals between populations, which may help prevent the negative effects of inbreeding and reduced genetic diversity (via genetic drift) that often occur with isolated populations.

The connecting habitat found in the area of Route 1856 links ecological communities in Costa Rica to those in southern Nicaragua. We agree with the EDA that "[s]ince the Route is critically located on the Costa Rica-Nicaragua border, it [was] of the utmost importance to analyze its potential impacts on the conservation of connectivity, based on the identification of priority sites and critical links for connectivity" (EDA pgs. 18-19). Existing disturbances and fragmentation of the corridor increase the

[2] Regarding the Great Green Macaw (*Ara ambiguus*) the EDA states that the project area includes locations within the "priority nesting area" and that are "key to the survival of the species" (EDA pg. 59). In other words, the project goes through the biological corridor that "constitutes the last viable habitat of less developed lands that can maintain the Great Green Macaw," which is "recognized internationally as a threatened species" (EDA pg. 60).

risk of significant impacts to Nicaragua. As the EDA notes, "the landscape has suffered a strong process of fragmentation that threatens connectivity among natural protected areas in Costa Rica and the southeast of Nicaragua" (EDA pg. 46). Construction of a road in such a location unquestionably has the capacity to create significant impacts in Nicaragua.

Screening would have found that clearing of primary forest for Route 1856 would likely impact Nicaragua in another way as well. Primary forests[3] provide ground cover and structural support for soils. Once trees and other vegetation are removed, soils are exposed to the elements and susceptible to erosion, particularly in locations like this one where there is abundant rainfall. This is a significant concern for this project location, where the "primary forest on sloping terrain" grows on soils with "very high susceptibility to hydric erosion" (EDA pg. 57). The EDA recognizes that this combination of rainfall and weak soils raises concerns about erosion and consequent impacts to nearby bodies of water: "Due to the high rate of rainfall in the area of the Route, the high grade of weathering of the geological materials, and the absence of forest cover in some specific sites, the existence of the potential risk of eroded sediments depositing on the different bodies of water has been identified" (EDA pg. 31). As a result, the project's proximity to the San Juan River and the many bodies of water that flow into the San Juan creates a risk of impact to Nicaragua.

4.2.3 Protected Areas

Screening would have found that EIA was necessary because the project location lies within protected areas, including biosphere reserves and conservation areas whose importance has been recognized on the national, regional, and international levels (EDA pgs. 20, 38-41). The location's biological diversity is "exceptionally diverse," and it is part of "the biological corridor with the greatest biological diversity in Central America" (EDA pg. 42), making it "one of the priority sites for biodiversity conservation in Mesoamerica" (EDA pg. 46). We agree with the EDA that it is important to conserve this "unique eco-system that protects a large number of species in danger or threatened by adverse effects that in many cases are generated by human activities" (EDA pg. 47, quoting a 2008 source), and that impacts to the eco-system assume heightened significance given the context. This makes EIA for projects in this location especially necessary.

[3] Some of the trees and other plants are themselves threatened and requiring conservation. The EDA acknowledges this, explaining that the project area is an important area for tree biodiversity (EDA pg. 47), and contains up to 28 threatened species of trees, 10 of which are endemic (only appearing in this particular location), and nine of which are "under threat of extinction" (EDA pg. 63). The area also includes "several flora species [that] are threatened, at least four endemic species" (EDA pg. 63). The details are provided in Charts 9 and 10 of the EDA (pgs. 64-65). Thus, as the EDA acknowledges, the project posed a basic but significant "risk of cutting down trees which are in danger of extinction" (EDA pg. 30) as well as other threatened plants that only exist in this location. The fact that there was already "a high degree of threat that weighs over a large number of lumber species in the Northern Territory" of Costa Rica (EDA pg. 65) made this potential impact all the more significant.

4.2.4 Existing Vulnerabilities

In determining whether the project had the potential to cause significant impacts, proper screening would have taken into account the environment's already stressed condition. This includes the already high sediment load of the San Juan River from sediments contributed by sources in Costa Rica.

Further, prior to the construction of Route 1856 there were "existing problems of fragmentation resulting from the expansion of the agricultural frontier" in Costa Rica (EDA pg. 39). According to the EDA, many species have already been affected "by the reduction of habitat as a consequence of deforestation and the fragmentation of forests" (EDA pg. 106), the latter of which was already "a serious threat to ecological connectivity as well as to the genetic quality of biodiversity" (EDA pg. 59). "Many species of flora and fauna depend on the conditions of these forest remnants" (EDA pg. 59).

These facts indicate the ecological importance of the area and that care was necessary to prevent environmental impacts. Activities that might have produced less significant impacts when carried out on a less compromised environment may be more serious, causing more significant impacts, as the result of existing damage and weakness.

The construction of Route 1856 has the capacity to cause increased sedimentation of waterbodies, including the San Juan River, as well as increasing deforestation and fragmentation of forests. Based on the existing conditions described above, proper screening for EIA would have identified such potential impacts as significant and required EIA so that the project could be properly managed to produce less significant impacts.

4.2.5 Post-Construction Impacts

Screening would have found that Route 1856 could cause impacts not only during the construction phase, but also after the road became operational. Impacts could include noise, dust, and hydrocarbon pollution from vehicles (all of which can also take place during construction), which can impact species and water quality and otherwise impact the environment. Traffic on unpaved roads like Route 1856 increases erosion and sediment transfer to bodies of water, particularly in the absence of appropriate compaction, drainage management, and erosion and sediment control. EIA was necessary to assess these impacts.

Roadways can cause significant visual impacts – i.e. a degradation of the aesthetic appeal of the project area – that give rise to a need for EIA. This risk increases when construction requires a swath of forest to be cleared along the right of way. It is also heightened when the project is located in areas that are relatively pristine, as is the case with parts of Route 1856. Roadway construction under such circumstances risks negatively impacting the value of scenic areas.

The presence of a roadway also creates the potential for induced migration, the increased presence of humans, and attendant impacts. As the EDA acknowledges, "The construction of Route 1856 could attract settlers to the region, generating pressure on the existing services and infrastructure, as well as on the region's natural protected areas," including "greater vulnerability due to the impact on natural connecting areas, and to contamination due to human activities" (EDA pg. 65). Increased access into this biologically sensitive area also poses risks related to resource extraction, which has already been a problem for the area even without this thoroughfare (EDA pg. 45). This is an additional reason why EIA was required.

4.3 Conclusion

The potential impacts discussed above, all of which would have been identified had Costa Rica engaged in a proper screening of the project, are more than sufficient to require EIA. That is why some form of EIA is universally required for roadway projects such as Route 1856, as well as much smaller ones that are not sited immediately next to rivers or through sensitive biological areas. We are not aware of any EIA regime in which a project of this nature has not required an EIA. Most regimes, including Costa Rica's, require EIA for much shorter road projects even where the impacts to water, primary forests, and biodiversity are not so obviously present.

We understand that Costa Rica has taken the position that the need to conduct an EIA was displaced as the result of an emergency decree. We have been involved in the preparation of works implemented in urgent and emergency circumstances, and Costa Rica's decision to proceed without an EIA is not consistent with normal practice. For example, in the aftermath of the well-known earthquake in January 2010, Haiti faced serious health issues as a result of the lack of sanitation systems to collect and dispose of sanitary waste. Although an emergency, a limited EIA was still conducted, including the design of makeshift treatment disposal areas. In our view, there was no reason for Costa Rica not to carry out at least some form of EIA for Route 1856.

5.0 WHAT AN EIA FOR ROUTE 1856 SHOULD HAVE INCLUDED

5.1 The Goal of an EIA

Proper EIAs involve meaningful pre-project analyses to establish the environmental and social characterization of a project area in order to assess the magnitude of risk and the impacts likely to be associated with the development of the project. These assessments allow for the avoidance of unacceptable impacts and the preparation of management systems to continually improve environmental and social performance, ultimately resulting in better environmental and social outcomes.

A project's potential effects are determined based on specific professional project experience, consideration of issues identified during the early planning or scoping phase of the EIA, knowledge of the project area, and through consultation with affected stakeholders. The technical disciplines that should have formed part of the EIA for Route 1856 include: hydrogeology; hydrology; surface and ground water quality; geology and geomorphology; soil; natural and industrial hazards; aquatic ecology; terrestrial ecology; biodiversity assessment and protected areas; human and ecological health; and visual aesthetics.

EIA of Route 1856 should have included, at a minimum:

- Description of the baseline environmental and socio-economic conditions existing before project development against which potential effects could be assessed, managed, and monitored.
- Description of the environmental and socio-economic effects that may be generated by the project during its construction, operations, and closure/post-closure phases.
- Description of project improvements that should have been incorporated to address potential impacts.
- Development and implementation of an Environmental Management Plan that includes impact avoidance, minimization, reclamation, and/or compensation such that potential negative effects are mitigated. This encompasses the ongoing aspect of EIA: keeping impacts in check; monitoring; and fixing problems that arise through adaptive management.
- Development of monitoring programs to evaluate the accuracy of the predicted effects and to assess the mitigation measures implemented to determine if additional actions are necessary to achieve identified targets for regulatory compliance and best management practices.

The level of study required for an EIA is a function of the project's activities that have the potential for significant adverse environmental or social risk and/or impacts. At a minimum, EIA for Route 1856 should have covered all aspects of the physical, biological and human environment, and addressed risks and impacts to the affected environment, communities, and stakeholders. This should have incorporated a mitigation hierarchy that: (a) anticipated and sought to avoid impacts; (b) minimized such impacts where avoidance was not possible; and (c) offset or compensated for residual impacts that remained despite best efforts and avoidance and minimization. In assessing and addressing risks and impacts, the EIA for Route 1856 should have considered all phases of project development, including design, planning, construction, and operation.

5.2 The Steps in an EIA

5.2.1 Clear Project Description

The EIA for Route 1856 should have included a detailed description of the proposed project, including its intended purpose and all the components and activities that would constitute it. This should have included, at a minimum, description of the background of the project; the extent and condition of the existing road network; proposed staging areas; areas to be cleared of vegetation; proposed location and sources of borrow materials and disposal sites; proposed equipment; and construction scheduling.

Such a description of all project components is necessary to define the scope of the EIA. A description of project allows for an understanding of the project activities and components so the proper project area of direct and indirect influence can be defined. The area of influence helps to define the baseline studies required to assess the anticipated potential impacts from project activities.

A detailed description of the Route 1856 project, including the proposed activities, would also have helped to serve as a basis for planning the biophysical and social baseline programs needed by providing the information necessary to understand which of the project's elements required environmental evaluation so that design modifications could be made, as needed, to avoid, minimize, or mitigate potential impacts.

A clear understanding of the project's purpose and components was also necessary for establishing which engineering criteria were relevant for the project, which is something that the EIA would have considered for Route 1856. This should have included determination of, among other things:

- Category (rated use: light versus heavy weight) and type road (soil or gravel)
- Design geometry (maximum radius), slope, maximum vertical grade
- Design speed
- Roadway specifications
- Intent and limitation of the roads
- Service level of the road
- Stormwater, erosion and sediment control

- Right-of-way and buffer zones from water bodies

Without a clearly defined project, it is not possible to establish which design criteria and engineering specifications are relevant. For instance, a small unpaved road that is not intended for use by heavy trucks can be built differently and in a different location than a large highway intended for use by commercial traffic. A roadway that has been built pursuant to one set of specifications may not be fit for different types of uses. Moreover, without the prior identification of design criteria and engineering specifications, there is a risk that the project will be developed inappropriately, e.g., without reference to any design or engineering norms (which is what appears to have happened in this case).

5.2.2 Scoping Study

The early planning or "scoping" phase of an EIA is the planning tool used to identify and evaluate the biophysical and social issues associated with the proposed project and to identify areas at risk of impacts. The goal is to ascertain which potential impacts require further assessment.

The Route 1856 project should have included a scoping study that, at a minimum, included:

- Constraint mapping of land use and sensitive areas (wetland, forest areas, protect areas), communities, buffer zones, water bodies, geology, natural hazards, constructability, and management of waste;

- Development of alternative corridors with the objective of selecting a corridor alignment that would require further investigation during the EIA; and

- Ground truthing, or site reconnaissance, to verify the selected corridor's existing biophysical and social conditions requiring further studies.

5.2.3 Alternatives Analysis

In light of the fact that Route 1856 had the potential to cause significant environmental impacts, alternative options should have been assessed for carrying out aspects of the project, so as to limit and/or mitigate potential negative impacts. This should have included an alternatives analysis to determine whether parts of Route 1856 should have been moved further away from the San Juan River to ensure that adverse impacts to Nicaragua were avoided and/or minimized.

5.2.4 Establishment of Baseline Conditions

After the selection of the preferred corridor through the scoping study and alternatives analysis, the EIA for Route 1856 should have determined the pre-project baseline conditions (prior to any project activity) based on a combination of field programs and, where appropriate, the most recently available literature with valid data on site pre-conditions. Discipline-specific studies should have been conducted in conjunction with the project design process to provide information to the project design team about environmental issues and constraints so that those issues and constraints could be incorporated into the design, construction, and operation of the project.

Baseline assessments are crucial in establishing the pre-project conditions so that predicted project-related effects can be compared to pre-existing conditions. Baseline studies for Route 1856 should have addressed, at a minimum: hydrogeology, hydrology and surface water quality; geology, geomorphology and soils; the area's biology and biodiversity; visual aesthetics; and natural hazards.[4]

5.2.4.1 Hydrogeology, Hydrology, and Surface Water Quality

As noted above, one of the risks of Route 1856 is that it would cause sediments to erode into bodies of water, including the San Juan River. Consequently, it was especially important for an adequate baseline to have been established for the watercourses in the road's potential area of influence. In that regard, collection of water and sediment samples from the San Juan River should have been conducted to enable comparison of pre- and post-Route 1856 environmental conditions. Water and sediment samples should have been required to be collected for their analysis of physical-chemical, organic and inorganic parameters and their relationship with ecological baseline conditions in order to evaluate the potential impacts.

5.2.4.2 Geology, Geomorphology, and Soils

As also noted above, the geology, geomorphology and soils of the relevant area influence whether sediments will erode into water bodies, including the San Juan River, as a result of the construction and use of Route 1856. Accordingly, the EIA should have included characterization of the area's geology and geomorphology.[5] Characterization of the soils should have involved the review of existing information, reports and literature including review of existing soil from geotechnical studies, geomorphology and topography baseline maps and reports; and review of existing soil and geomorphic information and literature. This is important for a road construction project of this type because it is necessary to ascertain soil type in order to design a road that can be supported in the location it is to be built. Certain soils cannot support steep slopes, for example, or are particularly susceptible to erosion and failure.

[4] A well-conceived EIA should also have collected baseline information on air quality and noise, which are areas of potential impact from roadway projects, as well as social components.

[5] This should have entailed collection of existing geologic maps, reports, and literature; review of existing geologic reports and literature including geologic strata, fault maps, seismic activity and unique geologic features; and review of maps and literature on erodible soils, landsliding and mass movement activity.

5.2.4.3 Biological Component

Biological baseline studies, at a minimum, should have evaluated the area's baseline aquatic ecology, terrestrial ecology, biodiversity, and interactions with protected areas. Further, International Union for Conservation of Nature (IUCN) List of Threatened Species, National Protected Species or Limited Range Distribution Species/Endemics, as well as species of local interest, should have been evaluated, so that appropriate planning, precautions, and measures could have been implemented before construction commenced. Since the nature of both terrestrial and aquatic habitats can change considerably during the wet and dry seasons, separate biological campaigns should have been performed during each season.[6]

In light of Route 1856's potential impacts to the San Juan River and its biota, baseline studies should have addressed its flora and fauna. At a minimum, they should have:

- Focused on locations likely to be disturbed by Route 1856;
- Included sites in the regional study area that may not be disturbed to enable potential future comparisons within the Route 1856 area monitoring;
- Focused on anticipated impacts associated with discharge and runoff, including increased suspended sediment loads from Route 1856 construction activities; and
- Identified human health concerns (i.e., contaminant loading in fish) and the extent of utilization of the fish that may be affected by sediment and chemical releases into the San Juan River.

Protected areas constitute both a source of potential tourism income and a way to conserve the natural and cultural heritage of the area. Under international (IFC) guidelines, effects on formal protected areas are taken very seriously. Effects must be minimized by choosing appropriate route sections and applying effective mitigations. Offsets to biodiversity and ecosystem services should have also been evaluated. In this case, effects on protected areas connected to the roadway via the San Juan River should have been considered.

5.2.4.4 Visual Aesthetics

Determination of baseline conditions for visual aesthetics should have been conducted using aerial views, satellite images and topographic maps available for the project area, as well as geo-referenced photographs that should have been collected. Particular attention should have been given to the collection of photographs from easily accessible key areas where potential receptors for visual

[6] With respect to terrestrial flora and fauna, baseline studies should have included proportional sampling of each habitat type across the area of influence in order to: characterize communities; identify species with special conservation status (national and international); identify species with traditional importance; and identify critical habitats and ecosystem services. Surveys for vegetation, amphibians and reptiles, birds and mammals should have been undertaken by conducting transects stratified by habitat type and impact versus control areas.

impacts exist, such as areas that are potentially of high scenic or cultural value along the San Juan River.

Baseline reporting should have included a rating of the visual aesthetics of the landscape in the key areas. The rating should have taken into account the baseline information gathered by other specialists such as geology, biodiversity and social and cultural resources. Baseline visual conditions should have focused on the rating of scenic quality (visual appeal of the land) and user sensitivity (including the public's attitude towards Route 1856).

5.2.4.5 Natural Hazards

EIA of Route 1856 should have identified natural hazards that could cause failures in the proposed project, including those associated with seismic, geotechnical and extreme meteorological events. Environmental and engineering information for Route 1856 should have been assessed to determine requirements for mitigating the risks from natural hazards, including pre-planning slope stabilization, erosion and sediment measures and engineering the Route to accommodate these risks.

5.2.5 Impact Analysis/Assessment

After establishing the baseline, the EIA for Route 1856 should have superimposed the proposed project onto the baseline, in order to predict where, how, and how much the proposed project was likely to affect bio-physical and social environments. Since the baseline includes all existing disturbances, the project's predicted effects should have been considered together with existing effects. Thus, EIA should have accounted for "cumulative effects," or the likely environmental effects of the project in combination with those of other projects and activities that have been, or will be carried out, and which may overlap with the direct effects of the project.

Particular attention should have been paid to evaluating the risk of sediment erosion given the factors described above: abundant rainfall, weathered (erodible) soils, and many nearby bodies of water, including the San Juan River, which support important and threatened biodiversity in protected wetlands.

For the Route 1856 project, assessment of impacts should have superimposed not only the construction of the road itself on the baseline, but also all other components of the project, including borrow pits, access roads, disposal of waste materials, the clearing of vegetation, and so forth. It also should have assessed potential effects on the environment from all phases of the project: construction, operation, and decommissioning. This should have been accomplished by identifying the different activities likely to be conducted during the stages of the project, and describing their interactions with the different environmental components.

Evaluating potential effects of the project on the environment would have resulted in the identification of opportunities for project re-design to eliminate or minimize potential effects, or to mitigate them.

Impact analyses should have been performed for each relationship between project activities and the environment components. This consists of five (5) steps:

- Step 1 - Identification of project activities that could contribute to environmental or social change.
- Step 2 - Evaluation of the potential effects.
- Step 3 - Description of mitigations for potential effects.
- Step 4 - Analysis and characterization of residual impact.
- Step 5 - Identification of monitoring to evaluate and track performance.

Predicted impacts that remain following mitigation, or residual impacts, for the environmental component, should have been described using the following criteria: direction (i.e., whether the impact is negative, positive or neutral); magnitude; geographic extent; duration; reversibility; and frequency.[7]

5.2.6 Identification and Concerns of Stakeholders

EIA generally requires that key stakeholders and their concerns be identified through the consultation process. The EIA should have integrated the results of these consultations into not only identification of issues to be addressed in the EIA, but also into assessment of potential impacts and development of environmental and social management plans, as relevant. The development of appropriate mitigation and enhancement measures could have been established during consultation with local populations to capture their input.

5.2.7 Identification of Mitigation Measures and Preparation of an Environmental Management Plan

Based on the comparison of the baseline with the assessment of impacts, the EIA for Route 1856 should have identified mitigation measures and prepared an Environmental Management Plan (EMP), the framework to ensure that all issues identified during the EIA process are addressed through appropriate mitigation and monitoring. In particular, the EMP should have addressed:

- Terrestrial and aquatic water quality and erosion/sediment control
- Stormwater management

[7] Impact assessment criteria are based on professional judgment and the considerations of the impacts that are identified as particularly significant to stakeholders. The precise use of the above system varies as appropriate for certain disciplines.

- Biodiversity
- Waste management and hazardous materials management
- Air quality and dust emissions
- Noise

The EMP for Route 1856 should have considered the project design aspects that are necessary to prevent or minimize the occurrence of adverse social and environmental impacts as well as specific actions required to mitigate potential impacts that cannot be prevented or minimized. The plan should have been developed before the start of any construction activities and implemented specific actions to appropriately prevent, mitigate, manage and monitor the potential social and environmental impacts of the project during the construction and operation phases.

6.0 PROBLEMS WITH THE ROUTE 1856 PROJECT DUE TO LACK OF EIA

Costa Rica's failure to conduct an EIA for the Route 1856 project meant that the above assessments did not take place, such that impacts which could have been avoided have come to pass, and impacts that could have been minimized have occurred (and continue to occur) on a much larger scale than they would have if properly accounted for before and during the construction of the project. This is especially the case in regard to the uncontrolled erosion of large quantities of sediment into the San Juan River.

6.1 No Consistent Definition of Purpose and Scope

As described above, it is a foundational element of an EIA that it define what the project is intended to do and how that purpose is to be achieved. This, however, was never done by Costa Rica. As a result, the basic planning elements that are normally incorporated into an EIA were absent, namely: description of the project; identification of relevant engineering specifications; and assessment of project alternatives. This has had significant consequences for the road's impacts to Nicaragua.

The purpose of the project and the detailed description of what it is supposed to do should have informed which engineering standards were appropriate. The standards applicable when building a small access road that will not be used for large trucks are not the same as the standards applicable when building a larger highway. Depending on its purpose, Route 1856 should have been designed with roadway standards tailored to that purpose and sufficient to meet at a minimum one of the following standards: Costa Rican Ministerio de Obras Publica y Transporte (MOPT2010), Central American roadway design, construction and maintenance standards (SIECA, 2002, 2004 and 2011), and/or international Best Management Practices. In general, it does not appear that the Route was designed at all, let alone designed to meet any such design criteria.

The appropriate engineering design of Route 1856 would have required, at a minimum, permanent features like bridges and culverts to have been installed at water crossings in accordance with acceptable roadway standards. Instead, the construction of Route 1856 involved the creation of multiple crossings where excavated fill materials was introduced into streams, most or all of which lead directly into the San Juan River. Other engineering standards, such as proper compaction and the use of appropriate culvert materials, properly sized and located culverts, were ignored as well. The result was predictable: stream crossings are failing and causing damage to the roadbed, which is washing out, and to bodies of water, including the San Juan River, which can be seen in the massive deltas of road-derived sediment now visible in the river. A road that causes sediment to enter a river in quantities sufficient to result in massive deltas is totally unacceptable and, in our professional experience, constitutes environmental negligence.

These problems were obvious during our site visit, during which we observed numerous locations where the failure of defective and improperly constructed stream crossings has resulted in the formation of very large sediment deltas, as may be in seen in **PHOTOS 1**, **2**, and **3** from our site visit in May 2014.

PHOTO 1 - Location: RKM 18 (from boat, May 2014). Formation of sediment delta from erosion and lack of proper water management.

PHOTO 2 - Location: RKM 18.2 to 18.3 (from boat, May 2014). Formation of sediment delta from failed earthen fill stream crossing and other erosion.

PHOTO 3 - Location: RKM 20.3 (from boat, May 2014). Road section with improper stream crossing consisting of a log bridge that has resulted in constricted of water flow and the creation of sediment delta in the River.

The lack of an articulated purpose and relevant design specifications means that the Route might be used to transport hazardous material without having been designed to do so safely. This risks significant impacts to the San Juan River from contamination caused by vehicle failures, turn-overs and spills.

6.2 No Alternative Corridor Study

EIA for Route 1856 should have considered alternative alignment options for the road so that parts of it would have been located further away from the San Juan River, thereby reducing the likelihood of significant amounts of sediment or other road-related pollutants reaching the river.

In particular, candidate routes should have been identified based on route selection criteria, taking into account environmental, social, land use, engineering, safety, and cost considerations. Route selection criteria should have included (among other things) protected areas, protected species, habitat types, erodible soils, topography, soil stability, proximity to water bodies, access constraints, engineering and land cost, safety, constructability, and cumulative effects.

Comparative evaluations of alternative routes should have been conducted to eliminate relatively unfavorable route segments. A list of route segments or candidate routes should have been developed, documented, and evaluated using project specific criteria. Attention to environmental, social resources and land use considerations in route selection would have led to a preferred route that was more acceptable from biophysical and social compatibility perspectives. This assessment, had it been conducted, would have identified sections with inaccessible and steep slopes, erodible soils and stability issues.

This process, however, was not undertaken. As a result, the corridor where Route 1856 was built is not the preferred corridor that would have been selected through a meaningful EIA process. The consequence has been significant erosion into the San Juan River and the formation of massive deltas of sediment there.

For instance, steep cuts were made into highly weathered soils that cannot support them, with landslides occurring as a result. This was evident during our site visit, as may be seen in **PHOTOS 4** and **5**, below.

PHOTO 4 - Location: RKM 16.1 to 16.5 (from helicopter, May 2014). Steep cuts and slopes were constructed in these erodible soils at slopes that are not generally considered stable or recommended for these types of soils. Lack of planning, design and mitigation measures have all led to the conditions observed.

PHOTO 5 – Location: RKM 21.4 to 22.1 (from helicopter, May 2014). Section of the roadway that is too close to the river. The steep cuts that have been made to construct the road and lack of erosion and sediment controls have resulted in sedimentation of the river. The terraces constructed in the slope provide little control of erosive effects of water from storm events as evident from the erosion gulleys of the face of the cuts into the hills.

This has also happened in locations with complicated topography, including steep and uneven areas, such as in **PHOTOS 6** and **7**, and where cuts at the bottoms of hills receive substantial sheet water flow from above, a phenomenon that causes significant erosion, as may be seen in **PHOTOS 8** and **9**.

PHOTO 6 - Location: RKM 7.4 to 7.9 (from helicopter, May 2014). An example of lack of proper design and planning process that has located this section of the roadway through undesirable topography. This includes areas that are too steep, too uneven, or too high in comparison to the surrounding environment. The topography in combination with the type of erodible soils combined to create unstable slopes and erodible conditions that have resulted in the sediment loading to the river.

PHOTO 7 - Location: RKM 7.4 to 7.9 (from boat, May 2014). An example of lack of proper design and planning process that has located this section of the roadway through undesirable topography. This includes areas that are too steep, too uneven, or too high in comparison to the surrounding environment. The topography in combination with the type of erodible soils combined to create unstable slopes and erodible conditions that have resulted in the sediment loading to the river.

PHOTO 8 - Location: RKM 18.3 to 18.6 (from helicopter, May 2014). The relationship between topography and the management of storm water not properly managed has resulted in significant erosion. Earthwork activities employed to construct the roadway have resulted in exaction into steep slopes (due to the lack of appropriate route selection and design) to accommodate the roadway in steep terrain. The construction of roadways in steep topography has resulted in the acceleration of water moving over exposed soils, further resulting in erosion and sediment loading as a direct impact to San Juan River.

PHOTO 9 - Location: RKM 2.5 (from boat, May 2014). This section of the Route was constructed by cutting into the toe of existing slope that is very close to the bank of the San Juan River. The cut that was constructed into the hill is too steep and unprotected. The steep cut slope and the nature of the unprotected slope located at the toe of a fairly high hill will promote erosion as water will flow over the cut during periods of precipitation that will continue to cut the slope and produce sediments that will wash into the San Juan River.

Construction of Route 1856 involved the unnecessary clearing of vegetation, including primary forests that are threatened and needed by endangered species. This also resulted in increased erosion of sediment into the San Juan River, as illustrated in **PHOTOS 10** and **11**.

PHOTO 10 - Location: RKM 16.1 to 16.5 (from helicopter, May 2014). Excessive removal of trees to construct the roadway that has resulted in exposed and unprotected slopes leading to slope instability.

PHOTO 11 - Location: RKM 23.6 to 24.5 (from helicopter, May 2014). Areas of excessive tree cutting used to construct two routes in this area.

At least one large borrow pit has been created at the top of a hill, ensuring that sediment is transported down to bodies of water, including to the San Juan River. This may be seen in **PHOTO 12**.

PHOTO 12 - Location: RKM 7.4 to 7.9 (from boat, May 2014). Borrow pit used for extracting soils for the construction of the roadway. The pit constructed in high topography has been left open and subject to erosion from precipitation events without appropriate BMP.

More generally, much of Route 1856 was constructed far too close to the San Juan River and/or its tributaries, in violation of reasonable buffer requirements (e.g., the 50m buffer for river banks established in Costa Rica Forestry Law 7575 of February 1996). This is visible in many locations, including all of the photographs provided above.

In sum, in various sections of Route 1856, ill-conceived attempts have been made to place the road in steep, uneven locations made of weathered, erodible soil that cannot support the steep cuts that have been made and with no water management and erosion and sedimentation BMPs. Gravity and water act on the disturbances, causing failure of the works themselves and damage to nearby aquatic resources, including the San Juan River, because these works are so close to it and/or to streams that lead into it. These problems are precisely the issues that EIA process would have identified and taken into account, so that the most appropriate corridor was selected.

6.3 Lack of an Effective Environmental Management Plan

Even a well-defined project with clear engineering specifications and a design based on a careful route selection study requires an EMP, which serves as the primary tool for ensuring that environmental considerations are implemented on the ground. The EMP should stem from the impact assessment process and provide guidance for avoiding and minimizing environmental impacts.

At least during the project's initial phases, no EMP was in force to guide pre-construction activities, such as land clearing, temporary access roads, disposal of land clearing and vegetation debris, the types and controls needed, and mitigation measures required, as well the locations and methods of implementation. It is apparent that no such control was exercised over the project, which involved, among other things, excessive and apparently unplanned clearing, as well as the improper "disposal" of land clearing and vegetation debris in side-cast fills, which was dumped into streams, as described in the reports by LANAMME and CFIA.

The absence of an EMP has further resulted in, among other things:

- Excessive embankments;
- Lack of proper compaction of fills;
- Improper construction of stream crossings using the wrong materials, which are undersized and improperly installed, many of which are now failing, transporting fill and shards of culverts to the river;
- Failure to protect exposed slopes effectively, with geo-textile fabrics often improperly installed and not using the correct geo-textile, allowing them to deteriorate from exposure to sunlight without achieving their purpose;[8]
- Improper planting of vegetation on vertical slopes without creating benches to allow water to cascade down the slope, such that the slopes are eroded on the vertical direction;
- Failure to construct proper drainage, which has caused further erosion of unprotected areas (including fills and borrow pits); and
- Failure to install proper erosion and sedimentation control measures prior to earth moving activities and during construction.[9]

[8] Even when installed properly, geo-textiles cannot prevent the erosion of slopes that are excessively steep or experiencing mass wasting, as through landslides.

[9] At a minimum, Route 1856 should comply with the Costa Rica MOPT 2010 Manual, which sets the requirement of an Erosion Control Plan that should include all temporary and permanent measures to control erosion and sedimentation (see pgs. 104-105). The Central America SIECA 2004 Manual specifies the same requirements (see pgs. 150-26 and 150-27). Also, both road manuals specify that before removal of any vegetation or construction activity, preliminary works to control erosion around the project area should be implemented.

6.4 Lack of Mitigation and Monitoring

Based on our review of the reports submitted by Costa Rica and our inspection during our site visit, we conclude that Costa Rica has not undertaken either meaningful mitigation or monitoring efforts. In particular:

- The exposed slopes and poorly constructed segments of roadway and borrow pits adjacent to the San Juan River are continuing to erode into the river, creating impacts to water quality, aquatic habitats and species; this will continue until corrective action is taken to stabilize all road segments and exposed soils.

- Monitoring to ensure erosion and sediment control measures are working does not appear to be taking place in a systematic manner, as evidenced by the numerous locations of unprotected slopes and the lack of activities to correct erosion and sedimentation.

- No monitoring program to verify compliance with erosion and sedimentation control appears to be in place, even though it was recommended in the EMP (April 2012) and in the EDA (November 2013).

7.0 INADEQUACY OF COSTA RICA'S "ENVIRONMENTAL DIAGNOSTIC ASSESSMENT"

In this section, we critique the "Environmental Diagnostic Assessment of the Ecological Component" (EDA) dated November 2013, which was prepared by the Tropical Science Center and submitted as Annex 10 to Costa Rica's Counter-Memorial. The EDA is not a substitute for an EIA. Nor does it accurately report the existing impacts of Route 1856.

7.1 Not an EIA Substitute

As an initial matter, while the authors of the EDA may be qualified in their specific areas of expertise (geography, biology, forestry, tourism, and GIS), none of them appear to be civil engineers, or to have experience conducting EIA or evaluating impacts beyond biological assessments. They thus appear to lack the requisite qualifications to prepare an EIA for a major physical infrastructure project like Route 1856.

Further, an EDA is a fundamentally different tool than an EIA. According to SETENA Resolution 2572-2009, the Costa Rican regulation that guides the development of EDAs, the objective of an EIA is "[t]o verify the environmental viability of the project and propose environmental control measures before the decision is made" (see Appendix 1). This contrasts with the objective of an EDA, which according to SETENA, is to "[i]dentify negative impacts with an emphasis on pollution and risk, and propose environmental control measures" (see Appendix 1). In other words, EIA is intended to identify impacts in advance of a project being carried out so that they can be prevented, minimized, compensated, and mitigated, while EDA is intended to identify impacts after they have occurred. Thus, an EDA, even if properly carried out, cannot prevent or minimize impacts that have already taken place. The many differences between EIA and EDA are set out in a table included in Resolution 2572-2009, which is reproduced at Appendix 1.

It is for this reason that many of the recommendations made in the EDA have come too late. They have been provided after the fact and should have been implemented during planning and design (which, as discussed above, did not occur) or during construction. The EDA thus cannot achieve what it states to be one of its "specific objectives," which is "[t]o provide technical and scientific foundations that guide the Government of Costa Rica towards decision making in the design and construction of Route 1856" (EDA, pg. 16). By the time the EDA was prepared, most of the construction had already occurred without any engineering design having been undertaken.

7.2 Not a credible post-construction audit

At best, the EDA could identify the existing impacts of Route 1856. However, its many flaws prevent it from achieving this more limited objective.

7.2.1 Scope of EDA

The EDA focused exclusively on “the first 1000 meters from the right margin of the San Juan River towards Costa Rican territory” (EDA pg. 22). This defined scope of the EDA (depicted in the maps on pgs. 24-29 of the EDA), is arbitrary and unreasonably limited. It ignores any works conducted as part of the road project outside of the 1000 m strip, including access roads, which extend far past the 1000m limit of the study area and are part of the project (see EDA pg. 21 for “Location Map and Access Roads”), as well as the upriver 50+ km of the road along the land boundary with Nicaragua. By focusing on only part of the project, the EDA artificially reduces its scope and environmental impacts. This is a serious flaw because much of the project was carried out in areas containing wetlands, forests, bodies of water, and biological corridors beyond the 1000 m strip. It is not possible to “establish the environmental effect of the Route 1856 project” (EDA pg. 15) while ignoring so many aspects of the project.

More importantly, the EDA’s arbitrarily defined study area stops at the southern bank of the San Juan River. This lack of consideration of Nicaraguan territory is not an appropriate approach for identifying and assessing impacts, as the impacts identified above (Section 4.0) do not abide by international borders. This is particularly relevant in the case of the San Juan River, which is very close to the Road in many locations, and which receives essentially all the drainage from the Costa Rican land on which the project was carried out, a fact which the EDA itself acknowledges (e.g., EDA pg. 69).

In fact, the EDA accepts the need to “evaluate the conditions that were previously identified [i.e., the conditions discussed in the EDA] from the perspective of potential impacts on Nicaraguan territory.” It incorrectly claims, however, that it “was not possible to carry out the previous suggestion” because the authors were not permitted to conduct sampling in the San Juan River (EDA pg. 141). Lack of access for sampling does not mean “that it was not possible to analyze the results of the study in a larger context” (EDA pg. 19). Notably, most of the assessment reported in the EDA within Costa Rica did not involve sampling – a review of the literature was deemed to be sufficient. The same assessment could and should have been done with regard to the San Juan River.

Another serious flaw in the EDA is that it does not address or incorporate the findings of other studies and reports prepared within Costa Rica regarding the Route 1856 project. The Costa Rican Environmental Management Plan (April, 2012), LANAMME (May, 2012), and CFIA (June, 2012) provide important information about problems observed along the road, impacts to the environment, and necessary mitigation and remediation measures. We would have expected a proper post-construction audit to take such prior studies into account.

7.2.2 Methods and Conclusions

The assessment in the EDA is almost entirely qualitative.[10] The Modified Leopold impact matrix consists of a matrix with columns representing environmental factors (e.g. terrestrial flora and fauna, aquatic flora and fauna; and landscape) to be considered and various rows representing the 11 designated project impacts (deforestation along right-of-way, partial sedimentation of edges of wetlands neighboring the Route 1856, etc). For each of the impacts, characteristics were evaluated (positive, negative, intensity, extension, etc.). Values were assigned for each characteristic and used in an equation to evaluate the significance of the impact based on the numerical score calculated in the formula. The significance of the impact is based on the score (e.g. <25 is considered irrelevant and a score between 25 and 50 is considered moderate; and 50 to 75 severe impacts) (EDA Matrix of Importance of Environmental Impact MIIA, chart 23, EDA pg. 140).

The EDA's impact assessment is thus based on a subjective analysis that assigns numerical values to produce "quantitative" values to measure impacts and thus results in an apparently quantitative measure of what is really a subjective conclusion. As a result, the data set out in the matrix it presents can be manipulated to reach the desired conclusions. Further, these impacts have been evaluated in the absence of baseline data, which makes scientifically defendable comparisons difficult if not impossible.

Section 5 of the EDA identifies various environmental aspects having significant impacts; however, these impacts are discounted as irrelevant or only moderate when they are qualified in the EDA's Modified Leopold impact matrix in Section 6 of the EDA. The impacts are discounted due to the flawed assessment as described below and the fact that the EDA assessed only the ecological environment.

Chart 24 on pg. 142 of the EDA is described as a matrix of environmental impacts of the project in Nicaraguan territory, which the EDA states was derived from "the results of the analysis" of potential impacts on the San Juan River (EDA pg. 141). Chart 24, however, is blank, indicating that no potential impacts were evaluated. We thus do not understand the claim in the EDA that "analysis was done, of each of the potential activities that might generate an impact, in order to verify if the same could have manifestations on the San Juan River" (EDA pg. 141). It is evident that no such assessment was undertaken. Nor do we understand how the authors of the EDA could have assigned a score of zero in the column regarding "importance" of those impacts. Given the lack of evaluation, there was no apparent basis for scoring importance as zero, or for the EDA's conclusion that "it is not considered there could be any significant impact on the San Juan River" (EDA pg. 141).

[10] The only new sampling that was conducted to provide quantitative data relates to macroinvertebrates, and that sampling was not properly conducted. See Blanca Rios Touma, "Ecological Impacts of the Route 1856 on the San Juan River, Nicaragua" (July 2014), Section 4.C.

More broadly, the EDA suffers from a basic methodological flaw. The Route 1856 project should have been evaluated as a linear project with multiple impacted sites. Instead, the approach taken in the EDA was to treat the entirety of the road located adjacent to the San Juan River as a single site with various impacts, averaging each discrete, often significantly impacted, site over the entire length of the Road. This had the effect of reducing the impact. In other words, the EDA evaluated the overall project at a macro level, considering the project over its entire length adjacent to the River, so that its multiple impacted areas were diluted to an "irrelevant" or "moderate" impact when compared to the larger extent of the project. The EDA's focus on the entire corridor instead of individual problem locations, and the resulting discounting of impacts which have been spread out over a long distance, is not a proper approach.

7.2.2.1 Sedimentation of Bodies of Water

The effect may be seen in the EDA's classification as "moderate" the "[p]ossible impact on the quality of waters [in Costa Rica] due to turbidity caused by sediment." (EDA pg. 140, Chart 23). This is a serious underestimate of impact of sedimentation, which as shown in Section 6, is taking place on a very significant scale in numerous locations on and leading to the San Juan River. To identify sedimentation's impact as being only "moderate" within Costa Rica and of no significance to the San Juan River (see EDA pg. 141), the EDA appears to have discounted the erosion and sedimentation taking place at individual sites and considered those impacts only in the macro context of the entire river-adjacent length of the road.

This is improper. Based on our experience evaluating impacts, the various impacted areas where erosion and sedimentation are taking place should be considered in their local context and, without question, constitute significant impacts that require immediate remedial action. The EDA's treatment of the issue is not consistent with standard environmental impact assessment practice, which is guided by the principle that projects or activities should not result in erosion and sedimentation to a body of water. It certainly should not occur on the scale currently found in the San Juan River (which the EDA dismisses as being of no significance), or with the intensity found at numerous sites.

The EDA also exaggerates remediation efforts that have been undertaken to address the issue of eroded sediments being deposited in bodies of water. It claims that, "[a]s a preventive measure runoff control systems have been put into place, as well as sediment traps along the Route" (EDA pg. 31). Based on our in-person observations in May 2014 and our review of the available materials, it is not true that sediments have been prevented from reaching the San Juan River or its tributaries on Costa Rican territory, and there is no evidence of a meaningful monitoring program to ensure such protection.

Another source of sedimentation in bodies of water is the erosion and failure of the many stream crossings that have been constructed along Route 1856, nearly all of which have involved the placement of excavated fill material directly into stream beds (see Annex 6 to Counter-Memorial, pg. 27). The EDA correctly notes that many of these structures are "in poor condition" and that there is "[t]he possibility of collapse" (EDA pg. 30), but it does not expressly identify the connection between such failure and sedimentation of bodies of water. In addition, the EDA states that, to avoid collapse, "a periodic monitoring effort has been conducted of Rte 1856 by CONSEVI, promoting an adequate preventive control of the structures along the way" (EDA pg. 30). This is not an accurate characterization, because failures have not been avoided, as evidenced by the washed out stream crossings and culverts that have made their way into the San Juan River at various locations.

7.2.2.2 Land Clearance

The other impact the EDA identifies as "moderate" within Costa Rica is "[d]eforestation along the right of way and contiguous areas" (EDA pg. 140, Chart 23). We disagree that the impacts identified within Costa Rica are of only moderate significance, and with the EDA's conclusion that they are of no significance to the San Juan River (see EDA pg. 141). In fact, the large-scale cutting of trees, especially in primary forest, is a serious concern. Such clearing should have been avoided for the reasons discussed above: the fragile nature of such forests, the threatened and endangered nature of their flora and fauna, their already limited extent, the erodible soils upon which they sit, and their proximity to bodies of water, including the San Juan River, that are at risk of sedimentation when erodible soils have been exposed through clearing.

The EDA reports that 68.3 hectares of primary forest were cleared, in addition to 14.9 hectares of secondary forests (EDA pg. 132). (These figures ignore any clearing that took place outside of the 1000 m stretch immediately along the River, which means that the actual total of cleared or impacted hectares of forest could be substantially higher.) Given the foregoing factors (including the physical impacts resulting from exposing erodible soils to direct weathering for extended periods of time without its natural protected coverage, be it primary or secondary forest), this should have been classified as a significant impact. This is particularly true given that "most of [the impacted primary forest] (59.56 hectares, i.e. 87%) is located upstream of Boca San Carlos" (Annex 3, pg. 27), which the EMP characterized as the stretch of road that "exhibits the most rugged terrain with a stronger presence of water bodies … thus being the area most vulnerable to environmental damage" (EMP pg. 6).

According to the EDA itself, "the primary forest on sloping terrain is the most vulnerable" location where impacts may be irreversible (EDA pgs. 65, 67), and it has dry textured soils with "very high susceptibility to hydric erosion" (EDA pg. 57). This is also the stretch of Route 1856 that the EMP recognizes as "run[ning] parallel to the San Juan River," and where it recommends that the Road's "distance from the river should be assessed mostly on account of project integrity" (EMP, pg. 10). The EDA itself identifies this upriver portion of Route 1856 as "the most impacted due to the presence of several unstable slanting retention wall[s] that could create sedimentation, erosion and sediment plumes in the San Juan and its tributaries" (EDA pg. 69).

The EDA provides some additional indication about why the significance of tree clearing has been undervalued. It states: "Since this study does not have quantitative information and location for the non-altered primary forest ecosystems, it is assumed that the forests characterized as primary are for the most part altered forests" (EDA pg. 67). This statement is not sound. A lack of information about the location of non-altered primary forest does not justify the assumption that primary forests have been altered. It is also contradicted by the fact that the EDA notes it was possible to observe "non-altered primary forest" in the direct area of influence of the project (EDA pg. 67).

The EDA further appears to have been mistaken when it states that "[t]he quantity of trees cut down was determined by the needs of each section of the route and the existing plant cover" (EDA pg. 144), and that the clearing of endangered trees "was minimized as a result of the tree inventory performed by [CONAVI] during the construction of the project" (EDA pg. 30). This implies a level of pre-construction planning that does not reflect what actually happened.[11] No evidence of this inventory appears in any of the documents submitted by Costa Rica, and there is no indication that construction was carried out in an organized way involving guidance from an inventory. To the contrary, the EDA states elsewhere that "It has not been possible to determine the impacted flora species, nor to provide a geo-reference for them, due to a lack of a prior inventory of the existing tree species" (EDA pg. 68).

7.2.2.3 Impacts to Biodiversity

As explained above, primary forests are crucial for the conservation of biodiversity, both of the flora that makes up the forest and of the fauna that depends on the forest for habitat. Impacts in Costa Rica are highly relevant to Nicaragua given the biological connectivity in the project's area of influence, as well as existing problems of fragmentation.

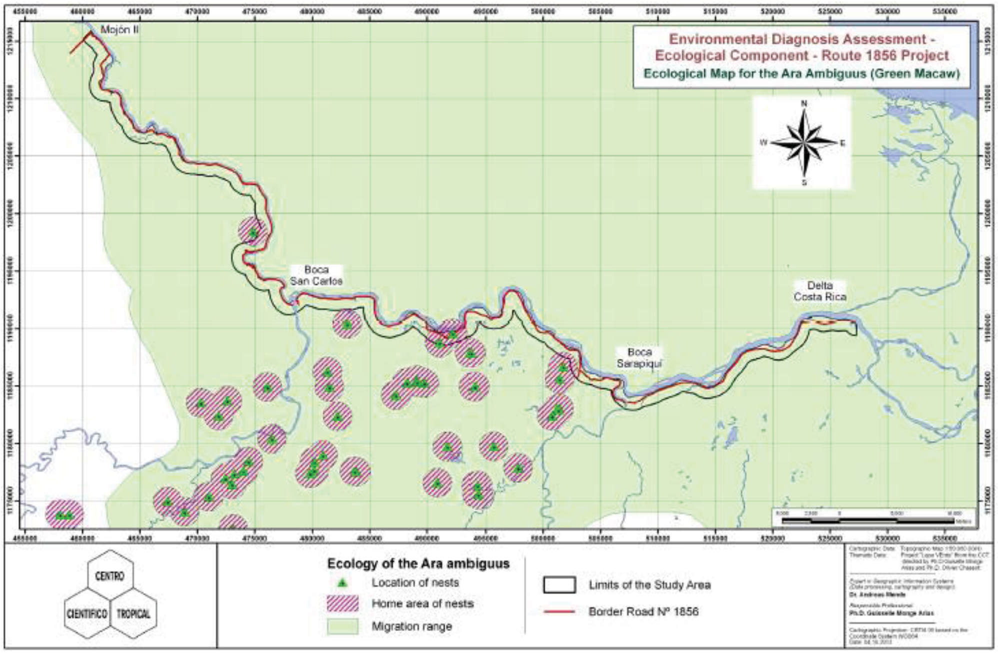
The EDA identifies potential impacts to biodiversity, but it dramatically underestimates the extent and significance of those impacts. This is particularly clear regarding the likely impact of the project on the Great Green Macaw (*Ara ambiguus*). As the EDA acknowledges, the project area includes locations that are its "priority nesting area" and which are "key to the survival of the species" (EDA pg.

[11] The same is true of the following claim in Annex 3: "The relatively small area of forest now used for Route 1856 reflects the fact that its route was planned to avoid primary forest as much as possible" (Annex 3, pg. 27). No such planning appears to have taken place, with the result being an inappropriate corridor selection, as discussed above.

59). Indeed, the Road goes through the biological corridor that, according to the EDA, “constitutes the last viable habitat of less developed lands that can maintain the Great Green Macaw,” which is “recognized internationally as a threatened species” (EDA pg. 60). We agree with the EDA that “[s]ince the Route is critically located on the Costa Rica-Nicaragua border, it is of the utmost importance to analyze its potential impacts on the conservation of connectivity, based on the identification of priority sites and critical links for connectivity” (EDA pgs. 18-19). However, the EDA’s analysis of impacts to the Great Green Macaw is not defensible.

The entirety of the EDA’s assessment on this point is that “[o]f the more than 100 known Great Green Macaw nests that are currently potentially active, only 3 of them (3%) are located in the influence area of Route 1856, so that the impact of this project on the Great Green Macaw population is considered irrelevant” (EDA, pg. 60). This is an untenable conclusion for an environmental impact assessment.

First, it is based on the incorrect assumption that it is possible to adequately assess impacts when only focusing on a limited portion of the total area impacted by a project. As can be seen in the map on pg. 61 of the EDA (reproduced below), the conclusion focuses exclusively on the narrow strip of land immediately adjacent to the River, when the remaining nests of this threatened species are located a short distance away in areas that have been impacted by the project’s construction of and “improvement” of access roads (see EDA pg. 21 for “Location Map and Access Roads”). If the EDA had accounted for the full extent of the project, it is likely that it would have identified much broader impact on the nests of the Great Green Macaw.



Second, an exclusive focus on nests ignores the fact that in assessing impacts to birds, one must consider not only where their nests are located, but also their foraging range. Road-related impacts could affect foraging areas, so that even if nesting was not directly affected other crucial activities could be.

Regardless, an impact to 3% of the population of an endangered species would be considered significant by international EIA standards, and it is improper for the EDA to dismiss as "irrelevant" such impacts (which, in any event, would likely be larger when the full project scope and the various activities of the species at issue are taken into account, and when future development as a result of the Road is considered).

7.2.2.4 Landsliding and Slope Erosion

As explained in Section 6.0, serious landsliding and erosion problems are apparent in various sections of Route 1856. The EDA identifies this impact, particularly in "the sector close to the Infiernillo [sic] River and the sector known as Chorreras," where it "has been occurring after the aperture of the Route and will probably continue to happen, as generally happens in these types of topographic settings and with soils that are susceptible to erosion"[12] (EDA pg. 133).

However, the EDA characterizes this impact as irrelevant within Costa Rica (EDA pgs. 140, 143) and of no significance to the San Juan River (EDA pg. 141). We disagree with this characterization. It appears to be based, at least in part, on the claim that "[i]n recent months the roadside slopes along the route have been protected along with the drainage systems at the same sites, to avoid landslides" (EDA pg. 146). A similar statement is made on pg. 30 of the EDA, which states that the risk of slope erosion and slope instability "has also been controlled with the placement of geo-textiles and, even better, with the planting of grasses on the slopes with the idea of diminishing the direct impact of rainfall on the exposed surface." Based on our observations in May 2014, these statements are serious exaggerations of the actual extent of such remediation works. There are many sites where landsliding and slope erosion appear to be ongoing, and where no protection or adequate drainage is evident. These include the sites exhibiting the worst landsliding and erosion problems, including those identified in Sites 8.1-8.2 and Sites 9.4-9.6 in the Inventory of Seriously Eroding Sites appended to the 2014 report of Dr. Kondolf, where it appears that no meaningful remediation has been undertaken.

It is notable that one of the environmental measures the EDA recommends for addressing the issue of landsliding and slope erosion is the use of geo-textiles (EDA pg. 147). Such erosion control fabrics can be useful in certain locations to prevent surface erosion, but they cannot prevent landsliding or erosion of slopes that are unstable as a result of having been cut too steep into soils incapable of supporting them. Moreover, our observations in May 2014 indicate that in many of the locations along Route 1856 where such erosion control fabrics have been installed, they are already failing, indicating that they may not have been properly installed nor the correct type of geo-textile applied.

The EDA itself states elsewhere that slopes "should be improved and mitigated for each specific case, taking into account first the degree of slope and, second, the composition of the geological materials in situ" (EDA pg. 144). This is correct – such remediation is now necessary because the project was not properly planned or carried out. But the reason such remediation is important is that the serious slope instability and exposure to the elements that are leading to landsliding and slope erosion have significant implications for the integrity and safety of the Road itself and for nearby bodies of water, including the San Juan River, which are being impacted by resulting sedimentation.

We also agree with the EDA that there are some sections of Route 1856 that are so unstable, because they were improperly located, that it is necessary "to evaluate the technical possibility of

[12] As discussed in Sections 5 and 6 above, these are reasons that the Road should not have been built in such locations in the first place, which a proper EIA would have helped prevent.

modifying the route … to include the use of local roads built on less sloping terrain, tracing the road some km to the south, where there are open areas and settlements with more favorable topographic conditions" (EDA pg. 147). This includes the stretch identified in the EDA near the Infiernito River, as well as others, which are identified in the report by Hagans and Weaver (2014). Fundamentally, this recognition by the EDA of the need to move the road is inconsistent with the unreasonable conclusion that landsliding and serious slope erosion are irrelevant impacts.

7.2.2.5 Aquatic Life

In describing the findings of the macroinvertebrate sampling, the EDA states that in impacted sites upstream of the San Carlos River, impacts were "observed in the community of aquatic macroinvertebrates, where the richness and abundance decreased at the points located downstream from the Route" (EDA pg. 98). The EDA goes on to explain that this result "could be attributed to two factors: 1) the degradation in the quality of the habitat, as a consequence of some activities that were part of the construction of the Route, such as the movement of earth and cutting down of river margin vegetation, 2) the process of sedimentation that occurs in the rivers, due to unstable slopes and landfills that are eroded by rainfall" (EDA pg. 98).

The EDA also reports that in various sites that "are found within the impacted segment of the Route," "the water quality went down in the downstream sites (with influence of the Route) with a moderate to bad classification and from bad to very bad in comparison to control sites found upstream" (EDA, pg. 99). The EDA goes on to state: "At sites located in the section classified as impacted (Infiernito River – mouth of the San Carlos River), the quality of the water was influenced by the works conducted in the Route, as were the richness and abundance of the communities" (EDA pg. 100).

These are descriptions of potentially significant impacts (although the lack of baseline information makes such quantification difficult). Nevertheless, these impacts are characterized by the EDA as "irrelevant" (regarding macroinvertebrate abundance/richness) or "moderate" (regarding water quality) when they are addressed in the EDA's impact matrix (Chart 23, EDA pg. 140). The reason for these valuations is not entirely clear (which is one of the problems with a subjective matrix-type approach), but it appears that a broad-based comparison of the highly impacted sites to the length of the project is again the explanation. The proper approach would have been to address each impacted site separately, with mitigation planned for it specifically, rather than broadly comparing each site to the overall extent of the roadway project.

The EDA's characterization of Route 1856's impact on aquatic flora and fauna as "irrelevant" within both Costa Rica and Nicaragua is also inconsistent with the statements in Section 5 of the EDA regarding the lack of information needed to make such a determination. The EDA states: "In order to evaluate with greater certainty if the works on Route 1856 created a level of sedimentation that could have an effect on the aquatic fauna of the San Juan River and its tributaries in the area of study, it is first necessary to determine and validate the thresholds of sedimentation that could affect the species found in these rivers, since there is no information for aquatic organisms in the area of study" (EDA pg. 111). It also notes the "need to determine and validate thresholds for morbidity and mortality of the species that are found in these rivers, as well as the level of tolerance to sedimentation since there is no information for aquatic organisms in the area of study" (EDA pg. 112). The EDA then goes on to explain that substantial work would be required to collect such information (EDA pg. 112).

The lack of background or baseline information does not mean the lack of meaningful impact, and these acknowledgements in the EDA regarding a lack of baseline information undercut the matrix's claim that impacts to aquatic life as a result of the road are "irrelevant." A proper EIA process would have dealt with gaps in background knowledge and should have accounted for the time it takes to acquire the necessary baseline information to assess the actual bio-physical conditions. This would then have been used to develop an assessment of potential impacts before construction commenced so that the risk of impacts could be eliminated or reduced prior to construction through alternative corridors, design, construction methods, and ultimately an EMP and monitoring.

EIA of aquatic life should have addressed and assessed related social impacts (e.g., how impacts to water quality and aquatic life might affect human communities dependent on those resources), and it should have engaged stakeholders through consultation to understand their socio-economic status, including how they utilize the river as an economic resource. The EDA does not engage on the issue of subsistence fishing. Although it acknowledges there is "sporadic, subsistence fishing" (EDA pg. 159), it did not analyze whether it has suffered any impact.

7.2.2.6 Visual Impacts and Tourism

The EDA identifies "landscape alteration" as an impact of Route 1856, saying that "[t]he exposed surfaces of slopes and road cuts at some specific sites along the tracing of the Route, contrasts with the forest, pastures and dominant farming field landscapes" (EDA pg. 134; see also pg. 150). In order to address this impact (which we consider to be an understatement, given the large expanses of exposed, unprotected dirt), the EDA recommends reforestation "in front of all road cuts that are visible from the right margin of the San Juan River" and indicates that corrections to landscape alterations are relevant for tourism (EDA pg. 150).

Despite these acknowledgements, the EDA categorizes the impact of landscape alteration as irrelevant in both Costa Rica and Nicaragua (EDA pp. 140-141). We disagree with this characterization, particularly as it relates to Nicaragua. As the EDA notes: "The tourism potential of the region is sufficient to justify attracting international visitors" (pg. 159). This potential is mostly associated with the natural beauty of this remote and non-highly commercialized region. The visual impacts associated with the road construction have created a scar on the natural landscape[13] that will have impact on national and foreign visitors along the river when viewing the riverine landscape, affecting the area's tourism potential.

7.2.3 Impacts Ignored in the EDA's Assessment

There are various issues that are identified in the EDA but not included in the impact assessment. Two of them bear mention here.

7.2.3.1 Use of the Road and Related Development

The impacts associated with the actual use of the road are not adequately addressed in the EDA. As explained above, these impacts should have been addressed in a proper pre-project EIA.

The impacts from the use of the road will vary depending on the actual driving conditions. As many of the sections of the road observed have only an existing soil profile instead of a gravel surface, these sections will have dust associated from vehicle traffic that are not only a concern to human health from the airborne fractions such as particulate concentrations of less than 10 microns, but to ecological and aquatic environments. Driving on unpaved road surfaces also contributes to erosion. The introduction of traffic necessarily means the introduction of fuel as well, which can drip onto road surfaces and be washed into nearby bodies of water. Spills from vehicles are also a concern, particularly in certain sections of the road characterized by inadequate compaction, uneven surfaces, unprotected banks and cut slopes, and unstable water crossings.

In addition to the impacts that can arise from the use of Route 1856, the road's presence involves the risk of additional impacts related to development, such as increased agricultural and/or commercial activities, or other human activities, as a result of the road's existence. Such increased human presence carries with it the possibility for increased adverse environmental impacts, including land disturbance, production of waste, and applications of pesticides and fertilizers, all of which are likely sources of pollution of the San Juan River and the sensitive surrounding areas. The EDA mentions these potential impacts related to increased human presence (EDA, pg. 65), but it does not include them in its assessment of impacts.

7.2.3.2 Hazards

Similarly, the EDA identifies hurricanes, tropical storms, and earthquakes as relevant in the project area (EDA pgs. 33, 35), but the implications of these hazards are not discussed in the EDA's

[13] These visual impacts are much more extensive than they needed to be because the road was not constructed pursuant to the standard of care for contractors working in the roadway construction industry nor according to any EMP, as discussed in Sections 5 and 6 above.

characterization of impacts. Many of the areas of exposed erodible soils and steep slopes along Route 1856 are in jeopardy from normal storm events. Due to slope failures, erosion, sediment washing into the river from poorly constructed sections of the road and slopes, the project area already exhibits significant localized sediment impacts. Larger events (earthquakes, hurricanes, storms) would result in larger sediment loading as well as compromising the integrity of the actual road. In addition to an increase in sediment loading from such events, the consequences of the repairs that would be required to reconstruct the road are likely to result in additional impacts from, among other things, construction activities, including earthwork movement, clearing of trees, and the creation of additional access to work areas. Contamination from fueling activities or other chemicals associated with repairs are further risks.

7.2.4 Conclusion

For all the foregoing reasons, the EDA's statement that "it is not considered there could be any significant impact on the San Juan River" as a result of the Route 1856 project is not supported or credible.

The EDA understates the impacts of the project in Costa Rica, listing as "irrelevant" or "moderate" impacts that are actually significant. Even the impacts that have been characterized as "moderate" within Costa Rica are treated as "irrelevant" to Nicaragua. There is no basis for this discrepancy, particularly when the EDA's study area and background information relates exclusively to Costa Rica.

Further, the claim that there is no impact to the San Juan River is inconsistent with the fact that many of the measures recommended in the EDA indicate that there are substantial impacts requiring attention (EDA pp. 144-155, 161-163), some of them directly relevant to the San Juan River. The same is true of the 2012 EMP, which makes explicit that remediation efforts of top priority (indicated in red in Annex 2 to the EMP) are those that are aimed at preventing impacts to the River.

In sum, Costa Rica's failure to conduct an EIA prior to constructing Route 1856 created a substantial risk of adverse environmental impacts to Nicaragua, including the San Juan River, a risk that, the evidence shows, has materialized.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The potential impacts to both Costa Rica and Nicaragua discussed above should have been more than sufficient to require EIA. That is why EIA is commonly required for roadway projects such as Route 1856, and smaller ones that are not immediately next to a river or through sensitive biological areas. In fact, we are not aware of any EIA regime in which a project of this nature would not require an EIA. Most regimes, including Costa Rica, require EIA for much shorter road projects even where the significant impacts to water, primary forests, and biodiversity are not so obviously present.

Therefore, the claim that this particular project did not require an EIA is contrary to both our professional experience and our professional opinion. Costa Rica's own EIA regulation would have normally required an EIA for this project (and even much smaller, less complicated road building projects). The claim that an EIA is not required is not valid.

Costa Rica has bypassed its national regulations that require an EIA for the Route 1856, it has ignored the executive decree protecting fragile protected area as previously referenced, has discounted the potential for significant impacts from the lack of pre-construction screening and design, has ignored the proximity of Route 1856 to the San Juan River and associated trans-boundary impacts, and still claims that the Route 1856 has not resulted in significant impacts. Route 1856 had the potential to cause a range of significant impacts, many of which are acknowledged in Costa Rica's EDA and EMP, as well as by studies conducted by Lanamme and CFIA, both well respected organizations, that contradict the statements made in the Costa Rican Counter-Memorial.

We recommend that:

- the Road not be allowed to persist in its current unprotected state;
- the Road not be used for the transport of hazardous materials;
- meaningful erosion control needs to be implemented;
- mitigation works need to be undertaken in a way that does not cause additional harm; and
- new development projects that can impact Nicaragua, now possible because of the Road, also be preceded by proper planning and EIA with Nicaragua considered as an interested stakeholder.

APPENDIX 1: TABLE FROM SETENA RESOLUTION 2572-2009

Variable	EIA	EDA
Objective of the Study	To verify the environmental viability of the project and propose environmental control measures before the decision is made.	To identify negative impacts, with an emphasis on pollution and risk, and propose environmental control measures.
Sign of the Impacts	Must identify and evaluate all the possible impacts: positive, negative, physical-chemical, socio-economic, biological, ecological, aesthetical, etc.	Identifies only negative impacts, with emphasis in pollution and environmental risk. In exceptional cases, EDA must include other impacts.
Type of Impacts	Must identify and assess direct and indirect impacts.	Identifies only direct impacts.
Area included in the study	AP (Project Area), AID (Area of Direct Impact), AII (Area of Indirect Impact), that is to say, all the environmental factors that interact with the project, inside and outside the property.	Except in exceptional cases, only AP and AID, trying to confine the environmental solution within the limits of the property or project, if possible.
Environmental Control Measures	Prevention, mitigation, and compensation	As far as possible, it must prioritize the environmental control directly in the "source" that causes the impact (the "environmental aspect" according to ISO 14001, recommended: Cleaner Production Measures (P+L), eco-efficient focus. This focus includes the management of impacts and risks.
Equipment	Necessarily interdisciplinary, to cover all impact and influence areas of the project. They must be registered as consultants in SETENA.	Not necessarily interdisciplinary; it depends on the type of project. The team can be smaller, and they must be registered as consultants in SETENA.
Flexibility	Inflexible, non-negotiable. The project must be 100% "environmentalized" from the very beginning.	Flexible, gradual, auto-evaluation, approval based in sworn affidavit, subject to verification through inspection and environmental audit.
Main output	PGA, dynamic, includes a program of environmental measures, a risk and monitoring program.	PAA (similar to EIA's PGA) and PCPA. The PAA must be dynamic, based on the indicators of environmental performance or monitoring. Gradual accomplishment goals in accordance with the demonstrated possibilities for each activity, and subject to SETENA's follow up through Inspection and Environmental Audit.

APPENDIX 2: AUTHOR CVS

Education

M.E. Civil Engineering, University of Florida, 1979

B.S. Civil Engineering, University of Florida, 1977

Certifications

Professional Engineer (P.E.), State of Florida (#35042), 1984

Languages

English – Fluent

Spanish – Fluent

Golder Associates Inc. – Gainesville

Employment History

Golder Associates Inc. – Gainesville, FL

Principal/Senior Project Manager (2000 to Present; Office Manager 2001-2009)

Senior project manager for international inter-disciplinary environmental projects, mining, oil and gas, transportation, power plants and LNG terminal environmental impact studies, compliance audits, air resources, environmental permitting, waste management services, and transactional audits in the U.S.

Golder Associates Inc. – Boca Raton, FL

Associate/Office Manager (1996 to 2000)

Responsible for technical, financial, and business development of the office on environmental impacts studies, compliance audits, air resources, permitting, waste management services, and transactional audits.

KBN Engineering and Applied Sciences, Inc. – Boca Raton, FL

Principal Engineer/Office Manager (1990 to 1996)

Responsible for technical, financial and business development of the office on environmental assessments, compliance audits, air resources, permitting, waste management services, and transactional audits.

Westinghouse Environmental and Geotechnical Services, Inc. – Deerfield Beach, FL

Senior Engineer/Office Manager (1984 to 1990)

Responsible for technical performance, financial and business development of a 20-man office providing geotechnical, construction materials inspection, environmental assessments, and asbestos management. Engineer-of-record on various high rise buildings, areas, convention centers, highway bridges, roadways, and environmental assessments.

McClelland Engineers, Inc – Houston, TX

Supervising Engineer (1982 to 1984)

Responsible for supervising staff engineers in geotechnical evaluations of high-rise buildings, highway projects, and offshore oil drilling platform projects.

McClelland Engineers, Inc – Houston, TX

Staff Engineer (1978 to 1982)

Project engineer on numerous geotechnical investigations and engineering evaluations of commercial, industrial and offshore projects. Lead Staff Engineer in Houston Transit Regional Rail System for the north and south corridors and 250-acre Flour-Daniel office complex in Sugarland. Performed geotechnical and geophysical investigations for major oil companies' offshore platforms and pipelines throughout the Gulf of Mexico. Co-engineer in developing a comprehensive map of subsurface sediment data of the Gulf of Mexico for Jack-up rig siting evaluations.

PROJECT EXPERIENCE – ENVIRONMENTAL SOCIAL IMPACT ASSESSMENT

Torex Gold Resources Ltd. Guerrero State, Mexico	Senior Project Advisor and Qualified Profession in the development of a Feasibility Study (FS) and ESIA for the Morelos Gold Mine in Mexico (Minera Media Luna S.A. (MML), respectively. As senior advisor, Mr. Susi has provide guidance to a multidisciplinary team consisting of engineers and scientist and interacts with the Torex project manager on all aspects of the FS and environmental and social studies to support the ESIA. Mr Susi has provided guidance, direction and assisting the MML and Golder project managers in the successful planning, execution of the ESIA. The Morelos Gold Project is located in Guerrero State, Mexico, approximately 200 km south–southwest of Mexico City, 60 km southwest of Iguala and 18 km northwest of Mezcala. The Project consists of three gold-enriched skarn deposits, El Limon, Guajes East, and Guajes West a dry tailings area, mill and surface water capture and treatment systems and supporting ancillary facilities.
Constructora Noberto Odebrecht, S.A. Dominican Republic	Project Director for 600 MW gas-fired power plant and LNG marine terminal in Pepillo Salcedo. A fatal flaw analysis was conducted for this project along the oceanographic studies to monitor currents and waves and physical and chemical parameters of the water column and bathymetry surveys of the bay for the offshore LNG terminal.
CF Industries San Juan de Marcona	Project Manager for an SEIA for CF Industries Nitrogen Complex consisting of a 2600 ton per day (TPD) ammonia plant and a 3,852 per day urea plant. Project Involves a multi-disciplinary team from Peru, US, and Canada that includes environmental and baselines studies, public consultation and workshops with affected stakeholders, impact evaluations and geophysical and geotechnical studies to support the preliminary engineering design. The SEIA is being conducted in accordance with IFC and Peruvian standards through the Ministry of Energy and Mines.
MKJ/Noble Energy Inc Nicaragua	Project Manager for the Social and Environmental Impact Assessment for the seismic exploration and exploratory wells for two concession areas cover 4,000 square kilometers (km) (approximately 988,396 acres) each located approximately 80 km from the coast in the Caribbean Sea offshore Nicaragua. The study involved the acquisition of 2-D and 3-D high resolution seismic studies to supplement existing seismic and geophysical. This phase of the project is the first of a three phase exploration and production of hydrocarbon resources on the Caribbean coast of Nicaragua.
Xstrata Dominican Republic	Project Manager of Environmental and Social Baseline for Impact Assessment of the Loma Miranda ferrous-nickel laterite mine, rehabilitation of the smelters at the processing plant by conversion of existing vertical furnaces to coal-fired kilns and the conversion of an existing 200 MW fuel oil fired power plant into a coal fired power plant in the Dominican Republic. Project involved an inter-disciplinary team from the U.S., Canada, Columbia, and Dominican Republic.
Xstrata Dominican Republic	Project Manager of Environmental and Social Baseline for Impact Assessment of the Loma Miranda ferrous-nickel laterite mine, conversion of smelters to coal and coal-fired power plant.

Panama Canal Authority
Panama City, Panama

Environmental Project Manager for the Feasibility Study of Palo Seco/Farfan Land Reclamation to develop a Port Facility. The project is part of the expansion of the Panama Canal and the possible construction of new sets of Locks. The study involved the beneficial use of excavation of dredged materials form the proposed new locks for the development of a major container transhipment center at the Pacific entrance to the Panama Canal.

The Phenix Group
Monkey Point-Corinto, Nicaragua

Project manager for an Environmental Impact Assessment (EIA) of the Interoceanic Corridor Project, which involves a 470-kilometer pipeline that crosses Nicaragua. The pipeline will carry crude oil and bitumen-based fuel from the Caribbean to the Pacific side of Nicaragua. The project involves transporting oil through an underwater pipeline to a terminal at Monkey Point for storage. From Monkey Point, oil would be pumped daily across Nicaragua to the Pacific port of Corinto through two underground pipelines. Tankers will load the oil again using offshore mono-buoys.

Panama Canal Authority
Panama City, Panama

Project Manager for the Environmental Feasibility Study of the Flood Mitigation Project for Gatun Lake, Panama. The project is part of the overall Master Plan for the expansion of the Panama Canal infrastructure, which included the evaluation of a new spillway and the increase the draft in the existing lock and Lake Gatun above the Maximum Operating Level.

Dead Sea Works
Ashdod, Israel

Senior Engineer for evaluating the risk of air-borne contamination of fertilizers from existing and proposed grain unloading operations at the Port of Ashdod. An evaluation of the existing grain unloading operations was conducted, a review of environmental studies performed at the site, review of meteorological data, and air dispersion analysis, and risk assessment.

Smith-Enron
Puerto Plata, Dominican Republic

Project Manager and Oil Spill Response trainer for the Puerto Plata Power Plant. Training included one-week of desktop and simulated oil spill exercises in the bay of Puerto Plata.

NRG Energy Inc.
Multiple Sites, South America

Project Manager for environmental due diligence of 10 hydroelectric power plants (4 in Bolivia, 5 in Peru, and one in Brazil). The environmental site assessment (ESA) purpose of this limited investigation was to identify potential recognized environmental conditions associated with the site and surrounding offsite properties and activities. The study involved reviewing of available regulatory permits, environmental studies, site maps, and photographs of the subject site and surrounding properties, interviews with plant personnel and review and evaluation of available geological, topographical, and hydrological information.

Hunt Oil
Pampa Melchorita, Peru

Project Director for an Environmental Impact Assessment (EIA) for 4.0 million metric tons per year Liquefied Natural Gas (LNG) Export Terminal and Marine Loading located in a greenfield site in Pampa Melchorita, on the west coast of Peru. The EIA is being conducted in accordance with World Bank and Peruvian standards. Project involved developing collection of terrestrial and marine baseline data, air dispersion modeling, cultural resources evaluation, public consultation, geoetechnical investigations, and the collection of baseline noise and air quality.

El Paso Corporation Baja, Mexico	Project Director and lead engineer for the EIA for a two-phase LNG Terminal in Baja, Mexico. The EIA was conducted in accordance to Mexican regulations and International standards. The first phase of the project consists of 610 MMSCFD capacity and the second phase has a maximum capacity of 1.2 BSCFD. Project involved developing collection of terrestrial and marine baseline data, air dispersion modeling, thermal discharge modeling, presentations to federal and state environmental agencies, and environmental mitigation and monitoring plans.
AES Corporation Andres, Dominican Republic	Project Manger and lead engineer for the EIA for a 300-MW gas-fired combined-cycle power plant and LNG import facility. The EIA was conducted in accordance to World Bank Guidelines. Project involved developing collection of terrestrial and marine baseline data, air dispersion modeling, thermal discharge modeling, social assessment report, public consultation, assistance with local approvals, and environmental mitigation and monitoring plans.
Transredes S.A. Santa Cruz - Yacuiba, Bolivia	Project Director for an Environmental Impact Study (EIS) for the 440-km gas pipeline for the Yabog South Gas Expansion Project in accordance with World Bank Guidelines. Project involved developing a scoping study, baseline studies, public consultation, and providing assistance with multilateral financing.
Coastal Power Company Pacora, Panama	Project Manager responsible for conducting an EIS for a 49-MW thermal electric power plant in accordance with Panamanian and World Bank Guidelines. Project involved air dispersion modeling to evaluate ambient air impacts and compliance with applicable standards for air, noise, and water quality.
Illinova Generating Company/Noresco Chorrera, Panama	Project Manager responsible for conducting an EIS for a 96-MW thermal electric power plant in accordance with Panamanian and World Bank Guidelines. Project involved air dispersion modeling to evaluate ambient air impacts and compliance with applicable standards for air, noise, and water quality. The project involved negotiating with newly-created regulatory agency Autoridad Nacional del Ambiente, the Inter-American Development Bank, and conducting public hearing and community relations' plans.
Cantarell Nitrogen Plant Cantarell, Mexico	Environmental Consultant to project sponsors consisting of Citicorp Securities Inc. and The Export-Import Bank of Japan, as well as other financial institutions, to provide independent technical evaluation of environmental aspects of facilities to supply nitrogen gas to Pemex Exploration and Production for reservoir pressure maintenance. The Nitrogen Plant located on the Gulf of Campeche, near Pemex Atasta compressor station will supply 1,200 MMSCFD of nitrogen for injection into the Cantarell area oil fields. The project consists of four large air separation units using conventional cryogenic air separation technology, 4 GE gas turbines and seawater cooling, pipeline and associated infrastructure.

Instituto de Recursos Hidraulicos y Electrificacion Various Cities, Panama	Project manager and lead engineer of a multi-technical staff of professionals responsible for conducting environmental site assessments (ESA) and compliance audits of the Panamanian electrical sector as part of the privatization and restructuring efforts funded through the International Finance Corporation (IFC). Site Assessments included 3 distribution regions with over 40 substations and supporting facilities, 4 power generation facilities that included 4 hydro-electric power plants and 3 thermal electric plants, and a 230kV transmission line. Each power plant site included an air audit consisting of regulatory and engineering analysis of combustion units, operating data, meteorological data and air dispersion modeling, and control technology. Other components of the study included noise measurements, health and safety evaluations, contamination assessments, soil and water analysis, and recommendations for compliance with applicable standards.
Unipharma, S.A. Bogota, Colombia	Project Manager and Environmental Assessor responsible for conducting an environmental assessment of an existing pharmaceutical plant. The environmental assessment included addressing past and current activities, solid and hazardous waste handling operations, wastewater discharge, and air emissions.
Land Sciences Corporation Kbasituri, Aruba	Project engineer responsible for geotechnical feasibility study in the development of a golf course community.
Gonzales Karg and Associates Mexico City, Mexico	Project engineer on a conceptual review of site-specific subsurface conditions; foundation design; construction techniques; the effects of development to adjacent and nearby structures and structural criteria; design concepts; and foundation loading including static; dynamic and seismic for Hilton Hotel International.
Various Oil Companies .Multiple Sites, Gulf of Mexico	Project engineer for siting offshore petroleum platforms.
Miami Arena Miami, FL	Senior engineer/project manager responsible for performing structural inspections and coordinating fabrication yard inspections from sister offices in Albany and Tampa.
Florida Department of Transportation Multiple Sites, FL	Senior engineer/project manager responsible for geotechnical engineering including soil surveys, laboratory testing, chemical analysis, and foundation design recommendations for the following bridges and roadway projects: 3-Mile S.W. 87th Avenue widening and reconstruction in Miami; N.W. 41st Street interchange in Miami; and Gratigny Parkway Expressway Bridge over N.W. 67th Avenue.

PROJECT EXPERIENCE – ENVIRONMENTAL PERMITTING

NexLube
Tampa, Florida

Project Manager for an 80,000 ton per year used oil re-refinery and blending facility in the Port of Tampa, Florida. The facility collects used oil as the primary feedstock and processes the used oil in a three-stage unit compromised of a pre-flash, thermal de-asphalting plant and hydrofinishing. Project involved siting study, air, stormwater, wetlands, local county approvals, civil engineering and bid specifications.

NexLube
Western USA

Project Manager for due diligence study for a confidential petroleum refinery, terminal, crude oil and product pump stations, pipelines in western USA. The due diligence project consisted of reviewing known-compliance issues, remediation projects, facility environmental and safety performance as well as pending or future environmental regulations that presented a material impact or influence the crude oil refinery to co-operate with a used oil re-refinery.

Moffat & Nichol
El Salvador

Project manager for the environmental advisory services Transaction Advisory Services for the Concessioning of the Port of La Union in El Salvador for a review of the status and completeness of existing environmental licenses available for the project; review and summary of the environmental management plans, licenses, permitting, contingent liabilities, and associated cost estimates for environmental related activities to be carried out by the relevant government agencies and to provide commentary on the opinion of the accuracy of the estimated costs associated with carrying out the prescribed environmental management plan, to identify gaps, and propose appropriate mitigation for addressing environmental issues.

Parker Drilling
Colombia and Mexico

Project Manager for evaluating environmental permitting checklist for assisting drilling managers to use during planning and start-up operations for new oil and gas rig drilling locations on country–specific regulatory permitting requirements or in the absence of such regulations as International Finance Corporation guidelines and Best Management Practices and company-specific standards and requirements.

Dixie Waste Services LLC
Dixie County, Florida

Project Manager and air permitting engineer for a waste gasification/thermal oxidizer (WG/TO) plant adjacent to an existing solid waste transfer facility in Dixie County, Florida. The facility is designed to burn 150 tons per day (TPD) of municipal solid waste (MSW), tire-derived fuel (TDF), and medical waste. The WG/TO process consists of a batch operation where incoming wastes delivered to the site by trucks are deposited in one of three (3) insulated primary gasification chambers (combustors) each having a capacity of combusting 50 TPD of waste. The project involved three public hearings to discuss the proposed facility, waste segregation plan and siting analysis.

Pratt & Whitney
West Palm Beach, Florida

Project Manager and air permitting engineer for various Title V renewal, RD-180 Program (rocket booster) and the relocation of two existing GG4-A9 JP8 fired engines from the Pratt & Whitney facilities in Hartford, Connecticut to the Palm Beach facility. The studies involved the preparation of an air construction/ operating permit applications to the Florida Department of Environmental Protection (FDEP).

Levee-Midway 500-kV Transmission Line Multiple Sites, FL	Engineer-of-record for all dredge and fill, management, and storage of surface waters and other environmental permits necessary to construct 152 miles of 500-kV line in five counties: Broward, Dade, Martin, Palm Beach, and St. Lucie. The following permits were included in this project: joint dredge and fill permit from FDEP and USACE; surface water management permit from SFWMD; and other permits as needed. Conducted hydrodynamic modeling of flow patterns (velocity, water levels, and flow rates) in the existing condition and the proposed transmission line access road with culverts condition, evaluated the impacts, and designed culverts to minimize impacts.
Florida Power & Light Company Martin and Palm Beach Counties, FL	Crane-Bridge-Plumosus 230-kV Transmission Line – Engineer-of-record for all dredge and fill management and storage of surface waters, and other environmental permits necessary to construct 42 miles of 230-kV line in two counties. Conducted hydrodynamic modeling of flow patterns (velocity, water levels, and flow rates) in the existing condition and the proposed transmission line access road with culverts condition, evaluated the impacts, and designed culverts to minimize impacts. Also responsible for as-built certification.
Florida Power & Light Company Multiple Sites, FL	Norris-Scottsmoor, Hobe-Indiantown, Hobe-Plumosus, and Hobe-Sandpiper Transmission Lines. Engineer-of-record for all dredge and fill, management, and storage of surface waters and other environmental permits necessary to construct approximately 75 miles of transmission line in Broward, Martin, and Volusia Counties.
Mulberry Ethanol Facility Bartow, FL	Engineering task manager for the design, alignment, permitting of a 2,000-foot rail spur constructed to serve the project. This project was constructed on a reclaimed phosphate mine area.
Florida Power & Light Company Hobe Sound, FL	Project manager and engineer-of-record for the restoration of 1.04 acres of tidal swamp wetland located on the Nature Conservancy Blowing Rocks Preserve on Jupiter Island. The restoration included the removal of exotic species, removal of spoil material, site grading to establish hydroperiod and the design of meandering tidal creeks with connection to the Intracoastal Waterway to provide flushing and habitat for wading birds.
McDonnell-Douglas Aerospace Titusville, FL	Engineer-of-record responsible for the preparation of annual air operating reports, preparation of air construction permits, air consulting services, and interfacing with Florida Department of Environmental Protection (FDEP) to modify existing permits and exemptions.
United Technologies Corporation, Pratt & Whitney West Palm Beach, FL	Project manager and engineer-of-record responsible for providing Title V air permitting services, including emission source evaluation, preparation of air permit application and negotiation, regulatory consultation, industrial wastewater permitting, and various permitting support activities.
Sensormatic Electronic Corporation Boca Raton, FL	Project manager and engineer-of-record for air construction and air operating permits, RACT evaluations, pollution control device evaluations, and Spill Prevention and Control and Countermeasure Plans for the Corporate Innovations Center.

Nailite International, Inc. Miami, FL	Engineer-of-record responsible for providing Title V air permitting services including emission source evaluation, preparation of air permit application and negotiation, regulatory consultation, and various permitting support activities. Prepared Tier II inventory reports (Section 312) and Form R (Section 313) for submittal to state and federal regulatory agencies.
United Technologies Corporation, Sikorsky West Palm Beach, FL	Project manager and engineer-of-record responsible for providing Title V air permitting services, including emission source evaluation, preparation of air permit application and negotiation, regulatory consultation, industrial wastewater permitting, and various permitting support activities.

PROJECT EXPERIENCE – ENVIRONMENTAL SITE ASSESSMENTS AND DUE DILIGENCE

NextEra Energy Resources, LLC Five States	Project Manager for a confidential project involving due diligence and support of a senior colleague seconded to NexEra to assist in the divestiture of five gas-fired generation facilities in five locations representing 2,700 MW of generating capacity.
Perez Compac and Consortium of Oil Producers Rio Colorado, Argentina	Project engineer responsible for conducting a pre-feasibility study and providing conceptual design systems to protect the sources of water supply at intake locations for potable and agricultural use along a 100-km stretch of the Rio Colorado. The study involved identification of critical contaminants, review of natural attenuation, and proposed alternatives for protection of water supply systems.
Puerto Nuevo Power Plant Facility Audit Buenos Aires, Argentina	Project Manger and lead engineer responsible for conducting the facility audit of site operations addressing solid and hazardous waste handling operations (including asbestos and PCBs) at the Nuevo Puerto Power Plant for RECA and ENRE. The audit included a review of waste handling, storage, disposal, and discharges into waters of the state. Health and safety issues were also addressed.
Puerto Nuevo Power Plant Facility Audit Buenos Aires, Argentina	Project Manger and lead engineer responsible for conducting a second facility audit of site operations addressing solid and hazardous waste handling operations (including asbestos and PCBs) at the Puerto Nuevo Power Plant for RECA and ENRE. The audit included a review of waste handling, storage, disposal, and discharges into waters of the state. Health and safety issues were also addressed.
Phase II Environmental Site Assessment for Transredes, S.A Arica, Chile	Project Manager responsible for assessment of soil contamination utilizing Risk Based Corrective Action (RBCA) applied to petroleum releases at a crude and diesel fuel terminal in Arica and a 150-km pipeline from Bolivia to Chile.
Pharmacia & Upjohn Multiple Sites, South America	Manager and Environmental Assessor responsible for conducting environmental assessments of various pharmaceutical facilities and sites in Brazil, Guatemala, and Colombia.

Resumé BENNY SUSI

A.D. Weiss Lithograph Company Hollywood, FL	Project Manager responsible for assessment of soil and groundwater contamination, development of interim remedial activities, preparation of contamination assessment reports, remedial activities, and liaison with regulatory agencies.
Broward County Convention Site Broward County, FL	Responsible for overall technical direction and coordination management of project that included soil gas surveys, geophysical surveys, soil sampling, contamination assessment, and long-term monitoring of shallow aquifer. Responsible for geotechnical engineering evaluation and recommendations, foundation installation monitoring, surcharge supervision, preconstruction survey, and construction materials testing.
Phase I Environmental Site Evaluation Multiple Sites	Project Manager and environmental assessor of over 50 Phase I environmental site assessments for commercial and industrial facilities throughout Florida and southeast United States.
Phase II Environmental Evaluation, FHP Manufacturing, Inc. Ft. Lauderdale, FL	Project Manager responsible for evaluating the presence and extent of soil and groundwater contamination, and preparation of an assessment report for this air conditioning manufacturing facility.
Captain's Creek Stuart, FL	Project Director of contamination assessment activities associated with underground storage tank.
National Crescent Petroleum, Ltd Karachi, Pakistan	Task engineer responsible for providing preliminary design criteria for land disposal of petroleum refinery hazardous wastes.
Sensormatic Electronic Corporation Boca Raton, FL	Project manager and engineer-of-record for an ESA (Phase I and Phase II), endangered and threatened species evaluation, and wetlands delineation.
Consultant for Port Everglades Authority Broward County, FL	Responsible for environmental assessments and audits, consultation, soil and groundwater investigations, and quality control oversight during a major port expansion during a 2-year service contract.
Isla del Sol Maintenance and Golf Course Facility St. Petersburg, FL	Project manager responsible for the assessment, removal, and disposal of contaminated soils associated with leaking underground tanks.
Stiles Corporation Ft. Lauderdale, FL	Senior engineer/project manager responsible for environmental audits prior to site acquisition, geotechnical engineering evaluation and recommendations, foundation installation monitoring, load test, construction materials testing, and structural inspections.
Various Oil Handlers Multiple Sites	Project director for the development of oil spill response plans for compliance with the Oil Pollution Act of 1990 (OPA, 1990).
City of Tallahassee Electric Department Tallahassee, FL	Engineer-of-Record for oil spill response plans for three power plants.

Enron Gas and Liquids, Brooker Terminal
Brooker, FL

Project manager and Engineer-of-Record for the development of oil spill response plans.

Clairison International
Ocala, FL

Project manager and Engineer-of-Record for the development of oil spill response plans.

Orange Cogeneration Facility, Orange Cogeneration, L.P.
Bartow, FL

Engineer-of-Record and task manger for preliminary subsurface investigation, geotechnical engineering evaluation, and environmental site audits.

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers

Tau Beta Pi, Honorary Engineering Society

Curriculum Vitae RENÉ LOZADA

Education

M.Sc. Wildlife Sciences, University of Tennessee, Knoxville, TN, U.S., 1991

B.Sc. Biology major in Ecology, University of Tennessee, Knoxville, TN, U.S., 1989

B.Ed. Biology and Chemistry, Universidad del Tolima, Colombia, 1987

Languages

Spanish (mother tongue); English (proficient); Portuguese (intermediate).

Golder Associates Inc. – Gainesville

Employment History

Golder Associates Inc – Gainesville, FL
Senior Environmental Specialist, located in Bogota, Colombia (associated with the Gainesville office since September 2006) (2006 to Present)

Project manager and environmental specialists in projects related with the oil & gas, mining, industry, power and transportation sectors in Central, Caribbean and South America.

Golder Associates Peru S.A. – Peru
Senior Environmental Specialist (2002 to 2006)

Project manager and environmental specialists in projects related with the oil & gas, mining, industry and transportation sectors in Peru and Latin America.

Golder Associates Bolivia S.A. – Bolivia
Senior Environmental Specialist and Office Manager (2000 to 2001)

Project manager and environmental specialists in projects of the oil and gas sector in Bolivia. General Manager of the Santa Cruz office, Bolivia.

WCI International Inc. – Colombia
Environmental Specialist and Office Manager (1998 to 2000)

Project manager and environmental specialists for oil and gas, power and transportation sectors in Latin-America including Colombia, Costa Rica, Ecuador, Guatemala, Perú and Mexico. General manager of the Bogota office, Colombia.

ACI Ambiental Ltda. – Colombia
General Manager and Partner (1997 to 1998)

Partner and general manager of the ACI Ambiental Ltda. dedicated to environmental inspections and audits to the oil and gas sector in Colombia.

Geoingeniería Ltda. – Colombia
Environmental Specialist and Project Manager (1994 to 1997)

Environmental specialists and project manager of several projects on the oil and gas sector in Colombia.

Corporación Autónoma Regional del Quindio – Colombia
Advisor & Program Director (1992 to 1993)

Environmental advisor at the Planning Department of this Regional Environmental Authority and the Director for the Research and Environmental Education Center – CIFAC.

United Nations Development Program – Colombia
Consultant (1991 to 1992)

Environmental specialists on the inventory of Government and NGO environmental initiatives in two country regions (Departamentos of Antioquia &

Choco) and evaluation for potential international funding under the context of the Colombian Program for Environmental International Cooperation.

PROJECT EXPERIENCE – OIL, GAS AND ENVIRONMENT

ACON LATAM MANAGEMENT LLC. Colombia	Environmental specialist and technical reviewer during the Environmental Review of Vetra´s company Oil and Gas Facilities in Colombia in accordance with the Equator Principles and IFC Performance Standards.
Transportadora de Gas del Perú TGP– Gulf Interstate Engineering Peru	Environmental specialist during the Independent Assessment of the Basic Design for the Camisea Jungle Loops Project. A review of environmental and natural resources issues derived from the basic engineering of the project and environmental studies under development. The project consists of two new NG and NGL pipelines of 144 kilometres to be constructed on the actual Camisea pipelines system between Malvinas and Kiteni, Perú.
CF Industries Peru S.A.C Peru	Environmental specialist and technical reviewer during the Environmental and Social Impact Assessment for a Nitrogen Complex Project.
Noble Energy & MKJ International Exploration Nicaragua	Project manager and environmental specialist for preparation of Terms of Reference and preparation of the Environmental Impact Assessment of the Oil and Gas Offshore Seismic Exploration Phase at Isabel and Tyra blocks in the Atlantic coast of Nicaragua.
Oiltanking & Consorcio Terminales (LQS) Peru	Project manager for Environmental Impact Assessment for the Construction and Operation of a Chemicals Terminal at the Port of Matarani, Arequipa. Terms of Reference definition, base line studies, environmental assessment, risk analysis and environmental management plan for a chemicals terminal to initially handle 16,000 annual tons of Sodium Hydrosulfide (NaHS), a product used as flotation agent in mineral concentrates production.
Hunt Oil Company Peru	Project manager for support in financial closure - environmental component with the International Development Bank - IDB. Interaction with the environmental consultant retained by IDB to carry out the financial closure for the LNG export project in the area of Pampa Melchorita, Cañete.
Hunt Oil Company Peru	Project manager for environmental assessment of an alternative marine construction method for the LNG Export Project, Pampa Melchorita. Comparative assessment of two construction methods and their feasibility during the marine construction works (breakwater and marine trestle) for the LNG export Project in Pampa Melchorita.

Perú LNG (PLNG) Peru	Project manager for Environmental Base Line Updating and Amendment to the Environmental Impact Assessment for the LNG Export Project, Pampa Melchorita. LNG export project in the area of Pampa Melchorita, Cañete. EIA amendment report preparation and submittal to the Ministry of Energy and Mines. Responses to observations and re-observations during the "EIA Amendment" review and approval as submitted to the environmental authority.
Oleoductos Premier de Nicaragua (Phenix Group) Nicaragua	Project Manager and Environmental Specialist for an Environmental and Social Preliminary Scoping Study of a 470 km oil pipeline using an Inter Oceanic Corridor across Nicaragua, from the locality of Monkey Point on the Atlantic Coast to the locality of Corinto on the Pacific Coast.
Mobil Oil del Perú S.R.L Peru	Senior reviewer for Health, Safety and Environmental Regulations Manual. Evaluation of Peruvian legal framework and its applicability to business units such as: Fuel Distribution to Aviation, Fuel Distribution Stations, Lube Oil Plant, Fuel Terminal and Fuel Distribution to Mining Companies. This evaluation will help to up to date and structure a manual on health, safety and environmental regulatory framework applicable to the above mentioned business units.
HUNT OIL COMPANY Peru	Project manager for Environmental and Social Impact Assessment for construction of an LNG Plant and marine facilities. Environmental and Social impact assessment for the construction of an LNG plant with a production capacity of 4.4 million metric tons per annum (MTMA) and marine facilities for export. This project is a key component of the Camisea natural gas exploration and production project.
PETROBRAS Ecuador	Senior review for Environmental Impact Assessment for the Development and Production of Block 31. Environmental assessment for the installation of a Central Processing Facility, water well pad, two production well pads with cluster wells (Apaika & Nenke), a road access, flow lines and export oil pipeline. The production platforms and part of the access road and flow lines will be installed inside of the Yasuni National Park.
ENCANA Ecuador	Auditor for Environmental Due Diligence to the Auca oil field. Evaluation of current facility conditions operated by PetroEcuador – PetroProducción on the production fields Auca Central, Auca Sur, Auca Este & Conga on the Eastern Ecuadorian, and identification of environmental liabilities under the current hydrocarbons regulations in Ecuador. These four fields are operating since 1970 and include 60 drilling wells, 41 production wells, two processing facilities (Estación Central y Estación Sur) and flowlines.
Lima Airport Partners Peru	Environmental specialist for Phase II audit to the EXXONMOBIL Fuel Terminal at the Jorge Chavez International Airport. This phase II work included an evaluation of the hydrocarbons contamination on the ground and related environmental liabilities with previous operations conducted at this fuel terminal.

TRANSREDES S. A Bolivia	Project manager for Environmental Impact Assessment of the Yacuiba-Río Grande Gas Pipeline Project. Environmental Impact Assessment and public consultation for the construction of a gas pipeline (36" diameter and 430 kilometers longitude) between Yacuiba, Department of Tarija (on the Bolivian-Argentinian border) and Rio Grande, Department of Santa Cruz, Bolivia. This gas pipeline will be constructed paralleled to the existing gas pipeline YABOG (24" diameter and 30-year operation) and will be joined to the Transbolivian Gas Pipeline (GTB), which transports the Bolivian gas to the border with Brazil.
TRANSREDES S. A Bolivia	Project manager Environmental Impact Assessment for a Compression Station and a 30-Kilometer Gas Pipeline. Environmental Assessment of the area for the construction of a compression station in Taquiperenda and a pipeline section of 30-kilometer and 36" diameter. This system will be integrated to the Gas Pipeline YABOG System (Yacuiba-Rio Grande pipeline).
CLHB S.A. Bolivia	Project manager for Phase II Environmental Audit in Refined Hydrocarbons Storage and Transportation Facilities. Environmental Inspection of 30 hydrocarbon storage terminals and the OCOLP products pipeline (Pipeline to Cochabamba – La Paz) to establish the investigation plan and evaluation of the environmental liabilities related to the former operator YPFB (Yacimientos Petroliferos Fiscales Bolivianos). These facilities were part of a transfer contract between the Bolivian Government and the Company CLHB S.A.
CLHB S.A. Bolivia	Project manager for Environmental Advisory on Refined Hydrocarbons Spills. Environmental Assessment and determination of the remediation measures required to areas affected by refined hydrocarbon spills originated at pipelines operated by CLHB.
TRANSREDES S. A Bolivia	Project manager for Environmental Impact Assessment of the Compression Station and 30-Km Gas Pipeline. Environmental Assessment in the construction area of a compression station in the town of Taquiperenda and a gas pipeline section (36" dm and 30 kms) to integrate the Yabog Gas Pipeline system (Yacuiba-Río Grande).
TRANSCANADA PIPELINES INTERNATIONAL Mexico	HSE auditor for El Bajio Gas Pipeline Construction. Audit of the HSE system and practices developed during the construction of the El Bajio gas pipeline project in the Mexican state of Aguas Calientes. This audit was part of a standardization of HSE practices between the Company and Techint, its main construction subcontractor.
CENTRORIENTE Gas Pipeline Colombia	HSE auditor for CENTRORIENTE Gas Pipeline. Audit to the HSE program implemented by the operator of the CENTRORIENTE S.A pipeline (Neiva to Barrancabermeja). This audit was part of the standardization program and internal policies of the Company.
CRESTAR ENERGY INC. Ecuador	Environmental auditor for Phase I to Block 16, a hydrocarbon production facility operated by REPSOL YPF in the Ecuadorian Amazon. The audit was carried out as part of the share purchase process by Crestar Energy Inc.

ECOPETROL
Colombia

Auditor for Environmental Audit to the Solid Waste Management in the Barrancabermeja Refinery. Auditor of the system and practices of solid waste management generated in the hydrocarbons refinery at Barrancabermeja. During the audit, the hazardous solid waste management, treatment and remediation strategies were reviewed.

ECOPETROL
Colombia

Project manager responsible for permitting and approvals and definition of environmental commitments with environmental authorities, prior to the start up of the construction of the products pipeline Poliducto de Oriente. This team was created by the Vice-presidency of Transportation at ECOPETROL, with exclusive dedication to the project.

ARPEL
Peru

Instructor and auditor for Environmental Audit Course. Instructor and auditor on the Environmental Audit exercise prepared to Petroperú S.A. and its facilities at an oil Refinery in Talara.

PROJECT EXPERIENCE – MINING AND ENVIRONMENT

Minera Isla Invierno
Chile

Environmental specialist and Technical reviewer for developing an Environmental and Social Management System along with Environmental and Social Management Plans in accordance with the Equator Principles and IFC Performance Standards for a Coal mine project in La Patagonia.

Torex Gold Resources Inc.
Mexico

Environmental specialist conducted a gap analysis in accordance with the Equator Principles and IFC performance standards & EHS sector guidelines of the Morelos Gold Mine Project in Nuevo Balsas State of Guerrero. Also, task leader for the flora and fauna baseline studies during the ESIA prepared for International Financial Institutions.

Goldcorp
Mexico

Environmental specialist during a Golden Eye Review of the Safety Management System of Goldcorp at Los Filos Mine, in Mazala State of Guerrero.

Minera Panama S. A.
Panama

Project Manager to coordinate a technical defense team and iterations with environmental authorities during review and approval process of the Environmental Impact Assessment conducted for the Copper Mine Project.

Pueblo Viejo Dominicana Corporation
Dominican Republic

Project manager and environmental specialist for preparing: Contingency and Emergency Response Plans for Hazardous Materials Management and Fuel Management for the Construction Phase at the Pueblo Viejo Gold Mine Project in accordance with IFC performance standards/EHS Guidelines and Dominican Republic environmental requirements. Also, preparation of the Waste and Hazardous Materials Environmental Management Plans for the Operations Phase of the Pueblo Viejo mine.

Pueblo Viejo Dominicana Corporation
Dominican Republic

Project manager and environmental specialist for the Amphibians Survey at control areas of the Llagal River Valley Project at Pueblo Viejo gold mine.

Xstrata Nickel Falcondo Dominican Republic	Environmental specialist and task leader for environmental baseline studies for the Loma Miranda Exploration Project and Coal Power Conversion Project. Coordination of terrestrial /aquatic ecology and social economical studies at project areas.
AURELIAN RESOURCES Ecuador	Project manager and environmental specialist for environmental scoping assesment of Fruta del Norte Mining Project. Coordination of biological baseline studies conducted in conjunction with Ecuadorian consultants at project area.
VOTORANTIM METAIS Guatemala	Environmental specialist and lead auditor for the project Fenix Environmental Due Diligence. Analysis and risk assessment for a potential property transaction at an operating mine in the Department of Izabal, Guatemala.
VOTORANTIM METAIS Colombia	Environmental specialist and lead auditor for Acerias Paz del Rio Environmental Due Diligence. Analysis and risk assessment for a potential property transaction at an operating steel factory and several coal, iron and limestone mines, located in the Department of Boyacá, Colombia.
MINERA MAJAZ S. A / MTB Peru	H, S & E project manager for Rio Blanco Feasibility Study – EIA Project Development. Analysis and risk assessment for a potential property transaction at an operating steel factory and several coal, iron and limestone mines, located in the Department of Boyacá, Colombia.
BHP BILLITON Peru	Project Manager for Flora and Fauna Baseline Study base for La Granja Mining Project. Evaluation of flora and fauna, rare and endangered species potentially distributed in the La Granja mining project area.
GENCOR-BILLITON Colombia	Environmental consultancy to the Cerro Matoso Expansion Project A review of standards and procedures accepted within the national legal framework and applicable to the iron-nickel mine expansion project activities of the Cerro Matoso S.A, Colombia.
GENCOR-BILLITON Colombia	Project manager for Flora and Fauna Assessment of the mine expansion project Cerro Matoso. Flora and fauna, rare and endangered species evaluation for the mine expansion project Cerro Matoso. The evaluation included the verification and identification of defined transects in the areas of influence and investigation of the following groups: birds, mammals, amphibians, reptiles and major plants.
CEMENTOS DIAMANTE S. A Colombia	Project manager and environmental specialist for Noise Level Studies at the Payande limestone mining site. Evaluation of noise levels at internal and external areas of the mine site in order to determine exposure levels and impacts on workers and neighbouring communities.

PROJECT EXPERIENCE – TRANSPORTATION, INDUSTRY, AND ENVIRONMENT

Johnson and Johnson Colombia	Project manager and environmental specialist for a Phase I Environmental Site Assessment at Yumbo and Cali facilities in Valle del Cauca, Colombia and a Phase II ESA at McNeil plant in Cali.

National Oilwell VARCO. Venezuela and Colombia	Environmental specialist for Phase I Environmental Site Assessment of industrial facilities in Barinas - Venezuela and in Acacias and Bogotá in Colombia.
YKK Corporation of America. Mexico, El Salvador and Colombia	Environmental auditor for Phase I Environmental and Regulatory Compliance Audits of two facilities in Irapuato, Mexico; one facility in Medellin, Colombia and one facility in San Juan Opico, El Salvador.
Corporación Andina de Fomento CAF. Peru	Environmental auditor during construction of a dam and water transfer tunnel in the Departments of Cajamarca and Lambayeque, Peru (Proyecto Trasvase Olmos).
AMCOR PET PACKAGING. El Salvador	Environmental specialist to conduct a Phase I Environmental Site Assessment of Plastiglas PET bottling facilities and operations in El Salvador.
Construtora Norberto ODEBRECHT S. A. Colombia	Environmental consultancy for the Ruta del Sol Highway Project, Colombia.
INTER-AMERICAN DEVELOPMENT BANK, CAF, China Development Bank, BNP Paribas and OPAIN Colombia	Project manager and environmental specialist for the EHS monitoring of a multilateral loan granted for the Expansion and Modernization of El Dorado International Airport located in Bogotá, Colombia
DP WORLD Peru	Project manager and environmental specialist to review social and environmental issues of a proposed expansion for the Callao Port North Container Terminal project.
INTER-AMERICAN DEVELOPMENT BANK Colombia	Project manager and environmental specialist for the Environmental and Social Due Diligence of El Dorado International Airport Expansion and Modernization Project, Bogotá - Colombia.
Construtora Norberto ODEBRECHT Dominican Republic	Project manager and environmental specialist for the Environmental Impact Assessment of El Coral Highway, a 70 kilometres road that will connect the airports at La Romana and Punta Cana in the Provinces of La Romana and La Altagracia in Dominican Republic.

AMCOR PET PACKAGING
Peru, Venezuela, El Salvador y Honduras

Environmental specialist for Environmental Base Audit of the Latin American operations in Venezuela, El Salvador, Honduras and Peru. Environmental review of AMCOR operations developed in five plants in Venezuela, one plant in El Salvador, one plant in Honduras and one plant in Peru. Operations in these countries are mainly oriented to transformation of PET resin into preforms and bottles for packaging of food products (water, sodas, oils and others).

ODEBRECHT – CONIRSA S.A
Peru

Project manager for Environmental Review of the Road Interconnection Project Iñapari – Puerto Marítimo del Sur (Stage I). A due diligence review of environmental baseline data and EIA report sections for the road sectors II (Urcos – Puente Inambari) and III (Inambari – Iñapari).

TERMINAL INTERNACIONAL DEL SUR S. A - TISUR
Peru

Project manager & environmental specialist for Environmental Impact Assessment for the renovation and expansion of existing concentrate copper storage and ship loading facilities at the Port of Matarani, Arequipa.

INTER-AMERICAN DEVELOPMENT BANK
Ecuador

Project manager and environmental specialist for Environmental and Social Review of the proposed New Quito International Airport Project. Review and assessment of the completeness and adequacy of Project environmental studies conducted to the new Quito International Airport in areas such as institutional and regulatory framework, natural hazards and vehicular traffic.

EXPORT DEVELOPMENT CANADA, US EXIM BANK & OPIC
Ecuador

Project manager and environmental specialist for Environmental and Social Due Diligence for the New Quito International Airport Project. Review and assessment of the adequacy of Project environmental studies conducted at the new Quito International Airport and the existing Mariscal Sucre Airport. Identification and summary of deficiencies in areas such as terrestrial and aquatic environments, environmental quality (noise), legal & institutional framework, natural hazards and vehicular traffic and transportation.

LIMA AIRPORT PARTNERS
Peru

Project manager & environmental specialist for Health, Safety and Environmental Action Plan and Organizational Structure for the Jorge Chavez International Airport at Lima (November. Environmental advisory to LAP top management on structuring a Health, Safety and Environment system to include current airport operations and ongoing reconstruction activities at airport facilities.

CIDA
Costa Rica

Environmental specialist for Rehabilitation Project of the Limon-Sixaola Road (NovAtel-CONAVI). A preliminary environmental assessment to the rehabilitation project of the Limon - Sixaola road (NovAtel-CONAVI) in Costa Rica, for the Canadian International Development Agency and BDLS.

PROJECT EXPERIENCE – POWER AND ENVIRONMENT

Colbun
Chile

Project manager and environmental specialist during a review of the environmental regulatory framework of a coal fired thermoelectric power plant in Colombia

Constructora Norberto ODEBRECHT Dominican Republic	Project manager and environmental specialist for a Fatal Flaw Analysis and Environmental Baseline Studies for a 600 MW Gas Fired Power Plant Project at Municipality of Pepillo Salcedo, Province of Montecristi, Dominican Republic
CIDA Guatemala	Environmental specialist for Pre-feasibility Studies of the Hydro-Electrical Project El Almendro. A preliminary environmental evaluation conducted for the pre-feasibility studies of the Hydro- Electrical Project El Almendro, Guatemala.

PROJECT EXPERIENCE – CONSERVATION, NATURAL RESOURCES AND PROTECTED AREAS MANAGEMENT

Corporacion Autonoma Regional CAR Colombia	Scientific Advisor for the Rehabilitation and Reintroduction program of the Spectacled Bear directed by the environmental regional authority CAR, Colombia.
Corporacion Autonoma Regional CAR Colombia	Environmental specialist for biological issues related to the Environmental Management Plan designed for the Upper Basin of the Sumapaz River.
The University of Tennessee, Knoxville United States	Research assistant in the Wildlife Science postgraduate program "Ecological Studies of the Black Bear in the Eastern United States" directed by Dr. Michael R. Pelton.
Wildlife Conservation International United States	Principal researcher in the Project "Evaluation of the Spectacled Bear Habitat in Colombia in the National Parks of Paramillo, Orquideas and Tatama and the Indian and Forestall Reserve Awa Kwaiker".
University of Tennessee and Kentucky United States	Field researcher for thesis project: Feasibility Evaluation of the Habitat of the Black Bear in the Big South Fork National River and Recreation Area.
Peregrine Fund and The Raptors Program at the University of Idaho United States	Field biologist in project: Study of Raptors Habitats in Tikal, Guatemala.
Industria Colombiana de Productos Electrofisiológicos Colombia	Researcher for study of the electrical activity of the heart in mammals and reptiles directed by Dr. Jorge Reynolds in Colombia and the United States.
Banco de la República, Biblioteca Darío Echeandía Colombia	Organizer and coordinator for environmental education program for children and teachers at elementary level.
Department of Natural Resources United States	Field biologist for black bear population study directed by Dr. David Garshellis.

Golder Associates

New York Zoological Society and World Wildlife Fund
United States

Field biologist for spectacled bear habitat evaluation projects in National Parks of Ecuador and Colombia, directed by Dr. Bernard Peyton and Dr. Jeffrey Jorgenson respectively.

Centro Nacional de Investigaciones Ecológicas
Colombia

Field ecology instructor and researcher for spectacled bear habitat evaluation project in the Colombian National Parks of Los Nevados and El Cocuy.

PROJECT EXPERIENCE – INTERNATIONAL COOPERATION AND INSTITUTIONAL SUPPORT

Instructor of the Environmental Assessment Workshop, organized to Corporación Autónoma Regional del Centro de Antioquia CORANTIOQUIA (a regional environmental authority),

Organizer of the Workshop - Seminar “Canadian Environmental Regulation of Hydrocarbon and Mining Projects” and binational coordination between the Ministry of Environment and the Ministry of Mines and Energy of Colombia (Subcontract with Iris Environmental Systems, Institutional Strengthening Program of the Canadian International Development Agency, CIDA-CERI). Colombia,

Environmental specialist for the evaluation of the program “Escuela Amiga” in the context of the Canadian Environmental Assessment Act; this program is developed by Plan International Ecuador and sponsored by the Canadian International Development Agency (CIDA). Ecuador,

Environmental Consultant for the Canadian International Development Agency project CERI-COLOMBIA-CIDA, Guidelines and Procedures for the Optimization of the Environmental Permitting and Follow-up Procedures Project, Institutional Strengthening Program for the Ministry of Environment of Colombia and Regional Environmental Authorities. Colombia,

PROFESSIONAL AFFILIATIONS

IAIA International Association for Impact Assessment

ICONTEC/ANDI Advisor, Standardization Committee ISO 14000 Colombia

Colombian Mountaineering & Climbing Federation

TRAINING & TEACHING

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ANNEX 7

Note from the Minister of Foreign Affairs of Nicaragua to the Minister of Foreign Affairs of Costa Rica, Ref: MRE/DM/645//12/13, 17 December 2013.

The Minister of Foreign Affairs
Managua, December 17, 2013

M R E / D M / 6 4 5 / / 1 2 / 1 3

Dear Minister:

I address in reference to the declarations given by the President of Costa Rica, Laura Chinchilla, who stated that they will continue with the construction works for the road parallel to the San Juan de Nicaragua River during this summer. President Chinchilla said at a press conference on December 13 that:

"…basically, several bridges will be duly installed for next summer… and some actual construction works will also be started…" for the roadway.

In the same sense, the Minister of Public Works and Transportation, Mr. Pedro Castro, stated in a press conference quoted, among others, by the press media *EFE* Costa Rica on December 13, 2013, entitled, "The Hague Court rejected Nicaragua`s lawsuit against Costa Rica" that *"the contract is already awarded to the company… for the design of the first 45 kilometer span".*

Nicaragua recalls that the Court pointed out in its Recitals to the Order dated December 13, 2013, that Costa Rica *"recognized during the course of the oral hearings that it has the duty of not causing any significant trans-border damage as a result of the construction works in its territory".*

Likewise, the Government of Nicaragua wishes to recall that barely a month ago, the Representatives of Costa Rica before the International Court of Justice, after acknowledging *"the need for mitigation works in the interest of mitigating the damages caused by the effects of bad planning and execution of the road works…",* declared to the Court that constructions works for the road would not be resumed until *"the end of 2014 or the beginning of the year 2015".* This declaration by the representatives of Costa Rica was taken very much into account by the Court in its decision as manifestly stated in its Order wherein it *"regretted that Costa Rica did make this information available beforehand".*

In this sense, Nicaragua not only regrets the declaration by President Chinchilla and by high-ranking officials while the same [officials] deny their affirmations made by their country before the High Tribunal and impinge against the good faith of the parties, but Nicaragua also requires Costa Rica to not continue with the construction of a material work that [Costa Rica] itself acknowledged that it has been poorly planned and executed, until it complies with its international commitments to guarantee that such work will not cause further damages to Nicaragua.

The Government of National Reconciliation and Unity calls upon the Sister Republic of Costa Rica to abstain from further acts that may aggravate or extend the controversy before the Court or to make it harder to resolve, in the same manner that it calls for due compliance with all of the commitments made before the International Court of Justice.

With no further matters, I avail myself with the opportunity to express the assurances of my consideration.

I avail myself with the opportunity to express the assurances of my consideration.

Samuel Santos López

Excellency, Mr.

Enrique Castillo Barrantes

Minister of Foreign Affairs

Republic of Costa Rica

ANNEX 8

Note from the Minister of Foreign Affairs of Costa Rica
to the Minister of Foreign Affairs of Nicaragua,
Ref.: DM-AM-704-13, 19 December 2013.

Ministry of Foreign Affairs and Cult

San Jose, December 19, 2013

DM-AM-704-13

Dear Sir:

I refer to your note MRE-DM-645-12-13, dated December 17, 2013, and dated December 17, 2013 in referenda to the Providence of the International Court of Justice, dated December 13, 2013.

The selective quotations that Nicaragua makes of the referred to Order, seriously distort the analysis of the Court and its unanimous decision. I remind Your Excellency that the Court rejected Nicaragua's position as to any evidence that construction of the Costa Rican trail caused any important damage to the San Juan River; hence, it rejected Nicaragua's request for indications of interim measures, including the request to suspend the construction works. Paragraph 39 of the Order clearly reflects this.

In reference to the Court's actual observance in regard to Costa Rica's commitments, I cite the following from the Order:

"37, Having concluded that no provisional measures should be indicated, the Court observes nevertheless that Costa Rica acknowledged during the course of the oral proceedings that it has a duty not to cause any significant trans boundary harm as a result of the construction works on its territory, and that it would take the measures that it deemed appropriate to prevent such harm. The Court further observes that Costa Rica has in any event recognized the necessity of remediation works, in order to mitigate damage caused by the effects of poor planning and execution of the road works in 2011, and has indicated that a number of remediation measures to that end have already been undertaken”

Therefore, as the Court observed, Costa Rica may continue improving the road located in its territory. Costa Rica never said that it would suspend the works, neither did the Court order Costa Rica to do so, as your note incorrectly states. Costa Rica has the right to continue performing the remediation, design and construction works with the purpose of completing this important infrastructure. Nicaragua’s request for interim measures was rejected preciselu because Nicaragua did not proof the existence of current or imminent trans-border damage derived from the road works.

My government regrets Nicaragua’s practice of distorting the scope of the decisions by the Court.

I take this opportunity to convey the assurances of my consideration.

Enrique Castillo Barrantes

Minister

Excellency
Mr. Samuel Santos
Minister of Foreign Affairs
Republic of Nicaragua

ANNEX 9

RESOLUTION 03-99 (XXI COMITRAN), Guatemala,
18 Nov. 1999

RESOLUTION 03-99 (XXI COMITRAN)

Standardization and Modernization of Technical Rules Applicable to Roads and Transportation by Road

THE MINISTERS OF TRANSPORTATION OF CENTRAL AMERICA

WHEREAS:

a. The Ministry has informed the Council that on September 30 an agreement with USAID [United States Agency for International Development] was signed for the execution of a project destined to improve the region's capacity to mitigate the effects of transnational disasters through the development of regional guidelines and standards focused on reducing the road system's vulnerability to natural disasters, that is, the execution of a work program focused on standardizing and modernizing the technical rules applicable to the roads in the region and to the transportation by road in Central America.
b. The Guatemala II Declaration in the Summit of Central American Presidents held on October 18 and October 19 this year called for concentrating efforts on reducing vulnerability and the impact of disasters, this being the objective of this project, which was recognized as an urgent priority in several prior meetings of the Council.
c. That for the execution of the agreement the Ministry has proposed the establishment of several regional work teams comprised of representatives from the Ministries of Transportation from each of the five Central American countries, in order to discuss and approve the proposals of specific consultants, who will be contracted by the SIECA [Central American Ministry of Economic Integration] for the development of each of the subjects selected.
d. That it is necessary to respond to the needs for construction and preservation of rural or neighboring roads in the region, given that they are linked to the main regional transportation arteries and are important for the economic development of the Central American region.

RESOLVE:

1. To convey through its Ministry, the SIECA, our most sincere thanks to the USAID for their support in the development of a project focused on improving the capacity in the region to mitigate the transnational effects of disasters through the development of regional standards and guidelines focused on reducing the road system's vulnerability to natural disasters.
2. To appoint, within the prudential term of fifteen days, a team of national experts who will be a part of regional work teams engaged in studying and approving proposals submitted to them for consideration by the SIECA, in each of the areas indicated below.

   - Updating the Central American Agreement on Roads Circulation of June 10, 1968, with special emphasis on motor vehicles' weight and dimensions;
   - Updating the Central American Manual for Roads Maintenance;
   - Preparation of a Central American Specifications Manual for the Construction of Regional Roads and Bridges;
   - Updating the Central American Agreement on Uniform Road Signs of June 10, 1958;
   - Preparation of a Central American Specifications Manual for the Geometrical Design of Regional Roads.

3. To provide SIECA with all the support needed to successfully develop a work plan related to this project.
4. To order that the Central American Ministry of Economic Integration (SIECA) take the action necessary to obtain financial support from the international community, prepare rules for the construction and preservation of rural or neighboring roads, and report back on the results of that effort.

Guatemala, November 18, 1999

ANNEX 10

Central American Manual of Environmental Norms for the Design, Construction and Maintenance of Roads (2002) (excerpts)

C.10.1 The cuts in most soils up to 10-15 meters tall (earth excavation), must be stabilized with slopes ¾: 1 to 1:1. In loose, gravelly and sandy soils, slope cuts of 1:1 to 1 1/2:1 is required.

ANNEX 11

Central American Manual of Specifications for the Construction of Regional Roads and Bridges (2nd. Edition Mar. 2004) (excerpts)

Central American Manual of Specifications for the Construction of Regional Roads and Bridges

In its XXI meeting done at Guatemala City on November 2009, the Sectorial Council of Ministers of Transportation of Central America (COMITRAN) approved Resolution 03-99 supporting the Program for the Modernization of Technical Norms applicable to roads and the transportation by roads.

Through a donation from the United States Agency for International Development, in accordance with Agreement USAID/SIECA No. 596-0181.20, titled “Better Capacity for the Region to mitigate the Transnational Effects of Disasters”, SIECA developed the component “Central American Manual of Specifications for the Construction of Roads and Regional Bridges.”

Consultancy’s Responsible Party: National Laboratory of Materials and Structural Models, Civil Engineering School, University of Costa Rica (LANAMME) SIECA/USAID CONTRACT No. 36-00

Technical Support Group: Engineer Mario Arce J; Engineer Federico Baltodano A.; Engineer Pedro L. Castro F.; Engineer Jorge A. Castro H.; Engineer Edgar G. Herrera J.; Engineer Gaston Laporte M; Engineer L Guillermo Loria S.; Engineer Marco A. Rodriguez M.

SIECA’s Coordination: Lic. Ernesto Torres Chico; Engineer Rafael Perez Riera; Lic. Raul Trejos Esquivel.

Regional Technical Group: Engineer Jose M. Gonzalez, Guatemala; Engineer Alejandro Salazar, El Salvador; Engineer Lorena Reina, Honduras; Engineer Amadeo Santana R, Nicaragua; Engineer Ernesto Rodriguez P., Costa Rica.

Guatemala, March 2001

2nd. Edition

Per the instructions of the Sectorial Council of Ministers of Transportation of Central America, COMITRAN, in its Resolution No. 04-2001 (COMITRAN XXIII), for the assessment on the operation and efficiency of the Central American Manual of Specifications for the Construction of Roads and Regional Bridges, with the purpose of maintaining it updated, this Manual was revised in September 2003 by the regional technical group:

Regional Technical Group: Engineer Jose Gonzalez, Guatemala; Engineer Edwin ALvarenga, El Salvador; Engineer Ivete Rodriguez, Honduras, Engineer Amadeo Santana, Nicaragua; Engineer Ernesto Rodriguez, Costa Rica.

SIECA Coordination: Lic. Ernesto Torres Chico; Engineer Rafael Perez Riera; Engineer Cesar A. Castillo M.

…

Guatemala, March 2004

PREFACE

This “Central American Manual of Specifications for the Construction of Regional Roads and Bridges” [is] published for use by the governments of the region, in compliance with the provisions of Resolution No. 03-99, issued at the Twenty-First Meeting of the Sectorial Council of Ministers of Transportation (XXI COMITRAN), that took place on Thursday, November 18 1999 in Guatemala City.

The primary objective of this COMITRAN resolution is the harmonization and modernization of technical standards applicable to roads and transportation by road in the Isthmus, in order to improve the ability of the region to mitigate the transnational effects of calamities
through the development of updated regional guidelines and standards which contribute to reducing the vulnerability of the road system in the event of natural disasters.

These specifications will be called "CA-2001, " being understood in all cases that the reference to the general specifications are the ones issued in 2001. When referred to in a contract, they will be considered an integral part of said contract and will be considered part of the offer and the contract.

204.09 Preparation of the foundation for the construction of the fillslope.

(a) Fillslopes less than 1 meter above natural ground. The clear soil surface shall be crumbled to a minimum depth of 150 mm, plowing or scarifying it. The ground surface shall be compacted according to Article 204.11.

204.10 Construction of fillslope. Add in the fillslope only adequate material excavated from the track. . . .

204.11 Compaction. Compact as follows:

. . .

(b) Fillslopes . . .

. . .

The material placed in all layers of the fillslope and scarified material in cut sections should be compacted to at least 95% of the maximum density.

Section 602. Culverts and drainage

. . .

Requirements for Construction

602.03 General. Use the same materials and coatings on all the sections of continuous pipe extensions and special sections.

602.04 Placement of concrete pipe and precast reinforced concrete boxes for culverts. Start by placing on the site of the lower outlet and place the bell or groove upstream. Fill all joints of sections completely. Place the circular elliptical reinforcing steel tubing, with the minor axis of the reinforcement, vertical. Build boards according to one of the following methods.

704.03 Fill Material. Use granular material and fine soil free of excess moisture, mud, roots, seeds, and other deleterious materials. All particles of rock and hard soil lumps larger than 75mm must be removed.

ANNEX 12

Central American Manual on the Maintenance of Roads (2010 Edition)
(excerpts)

PRESENTATION

In 2000, after Central America had advanced in the process of assimilating the damages caused by Hurricane Mitch in 1998 and realized that natural disasters do not distinguish political boundaries, countries of the region agreed that in order to address these threats, they should take actions and adopt technical rules applicable to roads, in order to reduce the vulnerability of their road network.

Therefore the Secretariat for Central American Economic Integration (SIECA) began to work on the development of a series of technical documents, aimed at harmonizing existing regulations in the region, related to traffic issues. This effort resulted in the publication, among others, of the Central American Manual on Maintenance of Roads. Once this process was completed, there was continued progress in the development of other issues relating to roads and road transport services, a situation that continues to date.

Comprehensive disaster risk management should be considered an intrinsic part of the planning processes and public investment, based on the social, economic, environmental and political-institutional dimensions of development, seeking to create comprehensive security conditions, as established by the Central American Policy for the Comprehensive Management of Risk Disaster.

In accordance with the above, a Memorandum of Understanding was signed on August 24, 2009 to implement the project " Standards for Roads" between the Executive Secretariat of the Coordination Center for the Prevention of Natural Disasters in Central America (SE-CEPREDENAC) and the Secretariat of Economic Integration (SIECA), which was developed with the help of external funding from the Spanish Agency for International Cooperation for Development (AECID)…

This Memorandum, whose objective is to improve the traffic situation and the vulnerability of land transport in the region comprised of Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama, contemplates updating this manual through technical training groups made up of representatives of the Ministries of Transportation and Civil Protection authorities.

The general conditions and specifications are intended to be applied mostly by the execution units of Road Funds established in each Central American country for road maintenance, based on the agreed unit prices. However, these specifications may also be used as a guide to regulate the quality of maintenance activities performed by direct administration, standards or concession projects.

This document presents the agreed rules for road maintenance using contracting based on unit prices, updating concepts in the edition of 2004, and incorporating valuable contributions of the countries contemplate in their hiring processes this methodology for road maintenance. In addition, this new edition incorporates tools for risk assessment and to reduce the vulnerability factors…

Ivan Morales Executive Secretary CEPREDENAC	Yolanda Mayora de Gavidia Secretary General SIECA

802. Cleaning of culverts and other drainage structures.

802.01 Description. This activity consists of the collection, extraction and removal of all materials which have been deposited in the section of the sewers, boxes and input and output channels, regardless of their respective dimension, including the cleaning and removal of all material found in other elements that make up the soil. It is necessary to keep in mind that these tasks are designed to achieve the fast channeling of the water through these systems.

ANNEX 13

Central American Manual of Norms for the Geometric Design of Roads (3rd. Edition 2011) (excerpts)

PROJECT DEVELOPMENT

After the project has been planned and programmed for implementation, the next phase is the development of the project (preliminary design). This phase consists of the following basic steps:

- Refinement of the purposes and needs;
- Development of a range of alternatives;
- Evaluation of alternatives and their environmental impact;
- Development of appropriate mitigation

. . .

FINAL DESIGN OF THE PROJECT

Once the best alternative has been selected and the description of the project is expanded by the EIA, the project goes to the final design phase. The final product in this phase is represented in several plans, specifications and quantities of materials and work to be used and carried out. . . .

4.2.2 Cutslopes

…The stability of the cutslope depends on the nature of the material encountered and the construction method to be employed. . . .

8.1.4 Risks in the Design of Superficial Drainage

Water is one of the elements that causes major problems on roads and paths because it decreases the resistance of soils, creating failures in fillslopes, cuts and bearing surfaces. This is why it is necessary to build efficient drainage to drain the water away from the project in the shortest amount of time. . . .

ANNEX 14

Affidavit of Ana Isabel Izaguirre Amador, 18 July 2014

TESTIMONY

DEED NUMBER TWELVE (12). -

NOTARIZED

DECLARATION. - In the City of Managua, at seven o'clock in the morning on July Eighteenth of the year Two Thousand Fourteen –**LESLIE MARIA CHAMORRO HIDALGO,** of legal age, married, Attorney and Public Notary of the Republic of Nicaragua, duly authorized by the Supreme Court of Justice during the five-year term that ends on March Twenty-ninth of the year Two Thousand Nineteen. – Appears **ANA ISABEL IZAGUIRRE AMADOR**, of legal age, single, architect and with domicile in Managua with citizen identification card number zero, zero, one, dash, eight, one, two, five, one, dash, zero, zero, two, six, Letter L (001-181251-0026L), who I attest to knowing her in this act, in which she acts on her own behalf and representation, and declares: **FIRST:** I am currently a technical advisor, specialist in risk assessment and disaster reduction within the National System for Prevention, Mitigation and Attention to Disasters (SINAPRED for its Spanish acronym) of the Government of the Republic of Nicaragua. I have held this position for eight years, my functions and responsibilities in SINAPRED being: technical advisor for programs, plans and projects related to comprehensive risk management; draft reports and studies on vulnerable locations; analysis related to zoning incorporating risk management variables, promoting inclusion of comprehensive risk management in territorial and local development processes. **SECOND:** In addition to being a SINAPRED Official, as previously stated, I have been part of the regional technical team to the Natural Disaster Prevention Coordination Center in Central America (CEPREDENAC for its Spanish acronym), as a comprehensive risk management expert in the processes leading to the regional harmonization and modernization of the technical standards applicable to road design, construction and maintenance, led by the Central American Economic Integration Secretariat (SIECA for its Spanish acronym) with Resolution 03-1999 (COMITRAN XXI), adopted by the Central American Transportation Ministries on November 18, 1999. Additionally, I know that the Republic of Costa Rica has actively participated in the elaboration of the regional technical manuals and standards referred to below. **THIRD**: The objective of Resolution 03-1999 (COMITRAN XXI) is to improve the capacity of the Central American countries to mitigate the effects of transnational disasters through the development of regional guidelines and standards and the incorporation of risk reduction elements for the road sector in SICA's member countries. **FOURTH**: In the performance of my functions, I have knowledge of: *Central American Manual of Specifications for the Geometric Design of Regional Roads (3rd Edition, 2011).* The first edition of the *Central American Manual of Specifications for the Geometric Design of Regional Roads* was approved by the Central American Ministries of Transportation on March 30, 2001 in accordance with RESOLUTION Nº 04-2001

(XXIII COMITRAN). Its second edition was published in 2004 by instruction of the Central American Ministries of Transportation in order to update its content. The third and last edition of the *Central American Manual of Specifications for the Geometric Design of Regional Roads* appeared in the year 2011. This Manual gathers the necessary standards and specifications to project the layout of a roadway, as well as the design controls and criteria based on traffic characteristics and the functional classification of the road or highway. Likewise, this Manual offers criteria and recommendations on matters relating to risk management and road safety so that the geometry designer can select the most adequate route to guarantee the physical integrity of the users and of the road infrastructure. **FIFTH**: *Central American Manual of Specifications for Construction of Regional Roads and Bridges (2nd Edition, March 2004).* The first edition of the *Central American Manual of Specifications for Construction of Regional Roads and Bridge,* which was elaborated under the responsibility of the National Laboratory of Structural Materials and Models, School of Civil Engineering, University of Costa Rica (LANAMME for its Spanish acronym), was approved in March 2001 by virtue of RESOLUTION Nº 04-2001 (XXIII COMITRAN). This Manual was updated in March 2004 for the last time. This Manual offers quality requirements and sets forth the most accepted standards during the different execution phases for road construction works, including land movement and excavation works; construction criteria and compaction of cut slopes and fill slopes; installation of drainage structures and erosion control systems, as well as the materials to use; proper management and exploitation of borrow pits; protection of material in waste deposit sites; and prevention measures to adopt during temporary suspension of works to avoid erosive processes; among other measures to ensure project feasibility. **SIXTH**: *Central American Road Maintenance Manual with a Risk Management and Road Safety Approach (2010 Edition).* The first edition of the *Central American Road Maintenance Manual* was published in the year 2001 as a result of Resolution Nº 03-2001 (COMITRAN XXIII). The Manual was updated a second time on October 2004. The last update of the *Central American Road Maintenance Manual* was in the year 2010. This Manual describes the different types of works – and the regularity with which these must be performed – for maintenance of all types of roads and to guarantee their useful life. These maintenance works include, among others: a) cleansing and repair of drains, sewages and erosion control works; and b) stabilization of cut and fill slopes by means of reforestation or the installation of mesh against landslides in order to reduce erosion. Furthermore, this Manual contains mitigation guidelines for damages caused by landslides or flooding. **SEVENTH**: *Central American Manual of Environmental Standards for Road Design, Construction and Maintenance (November 2002).* The main purpose of this Manual, approved pursuant to Resolution Nº 02-2002 (COMITRAN XXIV) in San Jose, Costa Rica on December 6, 2002, is to set forth the applicable environmental standards within the different construction phases for building a road – including the planning, design, construction and maintenance phases – to prevent, mitigate, correct and/or compensate environmental impacts associated with road construction, as well as those caused by natural disasters. For example, for the planning phase of road construction, this Manual provides that the layout of a road should minimize land movements, or that it should pass through the least amount possible of water sources. This Manual also provides that the recommended standards for cut slopes, depending on the type of soil, and the management of borrow pits with a focus on mitigating damages by erosion and natural disasters; it also recognizes the importance of building adequate drainage works when the road crosses water bodies, to avoid water impoundment, which causes transportation of mud and sediments, roadway deterioration, and affectations to aquatic flora and fauna. **EIGHTH**: These manuals serve as basis for the elaboration of domestic technical standards in each country of the region. In fact, the Republic of Costa Rica adopted its own *Manual of Specifications for Road Construction* in the year 2010, the content of which is almost identical to the *Central American of Specifications for Construction of Regional Roads and Bridges*. **NINTH**: **The Central American Manuals for Road Design, Construction and Maintenance and Route 1856**. As a SINAPRED official, I was designated by the Government of the Republic of Nicaragua to assess the impact of Route 1856, having made five land tours in the border area with Costa Rica, by air survey from Nicaraguan air space, navigation along the San Juan River and interpretation of satellite images. In my opinion, based on these field visits and cabinet analysis, as well as my professional knowledge, Route 1856 does not comply with technical guidelines and standards contained in the Central American Manuals for Road Design, Construction and Maintenance: unprotected and excessively steep slopes, uncompact fill slopes and without any protection, failed stream crossings, - all of these very close to the San Juan River -, including inadequate drainage systems for surface waters, are the most apparent evidence of non-compliance. Route 1856 does not contemplate any design elements leading one to conclude that it is within the technical standards established at the Central American level. Therefore, the construction works- as well as the characteristics presented in light of my knowledge, from the technical point of view- lack any prior planning pursuant to regional legislation. In some cases, both the horizontal and vertical alignments are next to the San Juan de Nicaragua River bank, this being the most critical technical component for current and future risk assessments. At these points, corrective and remedial measures are not sufficient and the risk persists. The points assessed present severe risks of flooding and erosion, causing sedimentation in the San Juan Riverbed. The natural physical conditions of the area, such as geological formations, poor quality soils, heavy rainfall and the proximity of the river are crucial for projection of a corridor requiring the study of new alternatives, moving away from the San Juan de Nicaragua River bank and outside of Route 1856. To date, it is evident that what has been done on said Route, in relation to the regulations, purpose and reasons for its opening, do not obey any technical proposal, nor any planning process duly applied. The location factor of the current Route is the result of a chain of non-compliance and disrespect to the commitments of the Central American Governments in the SIECA Manuals, mainly the above-mentioned Manuals. Since Route 1856 lacks the elements and regulations according to such Manuals, one can conclude that the roadway built by the Government of Costa Rica is out of any engineering standard according to the Central American Economic Integration Secretariat. I declare that the foregoing is, to my knowledge, true and accurate in its entirety. Thus, the Grantor expressed herself in this manner and I attest to having instructed her on the object, legal value and transcendence of this act; on the general clauses that ensure the validity of this deed, on the legal value and transcendence of the special clause it contains and that involves implicit and explicit waivers and stipulations. -

.- I, the Notary read this deed entirely to the person appearing, who is in agreement, approves, ratifies it without making any modifications, signs it together with me, the Notary, who attests to the entire narration. – (S) Ana Isabel Izaguirre Amador - (S) Leslie Chamorro H.-

PASSED BEFORE ME: FROM THE FRONT OF FOLIO NUMBER FIFTEEN TO THE REVERSE OF FOLIO NUMBER SEVENTEEN OF MY PROTOCOL NUMBER SIXTEEN, WHICH I KEEP FOR THE CURRENT YEAR AND UPON REQUEST OF **ANA ISABEL IZAGUIRRE AMADOR**, I ISSUE THIS FIRST TESTIMONY ON THREE USEFUL SHEETS OF LEGAL SEALED PAPER SERIES "N", NUMBERS 9367063,9367064,9559583, WHICH I SIGN, INITIAL AND SEAL IN THE CITY OF MANAGUA, AT SEVEN HOURS AND THIRTY MINUTES IN THE MORNING ON JULY EIGHTEENTH OF THE YEAR TWO THOUSAND FOURTEEN.

LESLIE CHAMORRO HIDALGO

ATTORNEY AND NOTARY PUBLIC

ANNEX 15

Nicaraguan Law 274 regarding the regulation and control of pesticides and toxic and dangerous substances, 1998, Art. 23(2)

Article 23. The following functions for the Ministry of Construction and Transportation are established:

1) To establish, regulate, control and supervise the air, water and land transport of Pesticides, Toxic and Hazardous Substances, and the like, and to prevent and address the risks arising from the transportation of these substances during their transport.

Transport units used for the mobilization and transport of products and substances subject to this law are prohibited from moving and transporting livestock or food products.
The by-laws of this Act shall establish the rules for the mobilization of products and substances regulated and subject to this Act;

2) In coordination with the Ministries of Health and Agriculture: to monitor, regulate and control the means of transport for applications, sprays or crop treatments using Pesticides, Toxic, Hazardous and Similar Substances through air in a perimeter of no more than four kilometers, and by land, fifty meters from towns, villages and water sources;

3) After verifying compliance with the basic requirements to preserve the environment, human, animal and vegetal health; and the standards of occupational health and safety, it may grant the corresponding operation License to service companies and operators who engage in aerial and ground spraying, and the transport of pesticides, toxic, hazardous and other similar substances.

ANNEX 16

"President Confirms Errors in Construction of Trail 1856",
El Pais, 24 May 2014
(http://www.elpais.cr/frontend/noticia_detalle/1/92093)

PRESIDENT CONFIRMS ERRORS IN CONSTRUCTION OF TRAIL 1856

2014-05-24

The first tour by Luis Guillermo Solis Rivera to the Huetar Northern Region to review the conditions of Route 1856 or "Border Trail", verified technical and planning errors decried during the previous government.

The initial ruling performed by the President of the Republic, the Director of the National Laboratory of Materials and Structural Models of the University of Costa Rica (LANAMME), Luis Guillermo Loria and the Minister of Public Works and Transportation (MOPT for its Spanish acronym), Carlos Segnini, agreed when *they stated that what happened with the Border Trail was lack of planning of the works, which caused deterioration of the project.*

The Minister of Transportation, Carlos Segnini, assured, *"We see road sections that respond to little or no planning and redesigns that imply expansion of at least one or two vehicles and placement of missing bridges, which are ready, but there is still much work to be done".*

On his part, Loria assured that everything that was visible responds to what Lanamme had already reiterated many times during the previous government.

"We ascertained what we have always said and if we provide it with proper geometry with a good design, this road may last for many years; what is happening at this time would not happen, where one does not know the technical criteria to which this construction responded".

In the meantime, President Luis Guillermo Solis revealed his concern over deterioration at specific points of the route, but stated that *the will of this government is that The Trail stops being a trail and turns into a road.*

The President stated, *"There is an important section that is indeed much deteriorated at a point where it comes too close to the San Juan River, and it might be important to redesign it because part of what had already been opened is already covered by vegetation".*

"I was surprised to see the number of places that require work in order to turn The Trail into a road".

Solis also stated the need to control what is happening in the terrain, given the current degree of abandonment of the border project, which would jeopardize part of the works to avoid illicit activities in the area; therefore, this part is also critical to his government.

“One can clearly perceive from the air how The Trail provides access to farms and people who live south of the border, but we must also close the spaces to ensure that no illegal activities are taking place; therefore, we need more control”, he warned.

During the tour, Rogelio Jimenez, official of the Conservation Area in the sector, showed the President illegally felled lumber during construction of The Trail, and the (President) decided that this material should be used by the Ministry of Public Education (MEP for its acronym in Spanish) to build school desks and infrastructure for education centers.

The presidential tour will continue this Saturday with visits to different regions in the Northern Area and to coastal posts in this part of the national territory.

ANNEX 17

"Trail Construction Will Restart at the End of the Chinchilla Administration", *crhoy.com*, 13 December 2013 (http://www.crhoy.com/precio-total-de-la-trocha-fronteriza-se-estima-en-mas-de-50-mil-millones/) (excerpts)

TRAIL CONSTRUCTION WILL RESTART AT THE END OF THE CHINCHILLA ADMINISTRATION

Total Price of the border trail estimates more than 50 billion Colones
In view of delays in procurement, strategy focusses on bridges

Payment requests by companies during the first phase of construction are still unsolved

DECEMBER 13, 2013

The Government took advantage of the ruling by the International Court of Justice to give details on how it expects to restart construction of the border trail. In view of difficulties to tender the works, the Ministry of Public Works and Transportation (MOPT for its Spanish acronym), focusses its work on bridges and to advance with the posting signs.

The National Emergency Commission granted a budget of 19 billion Colones, of which 3 billion are already invested and 16 billion remain for the remaining contracts in March. But Castro said that a budget increase of about 16 billion Colones will be required when the designs are defined.

In addition to the road, the company must design gutters, slopes and a bridge. This construction work begins in Los Chiles sector and the design must be ready by April. Afterwards, construction could be awarded and could begin in May.

Another for sections would still be needed. Design of two of these sections should be ready in May, as well as works in progress. In addition, the National Emergency Commission approved implementation of 4 tender cartels, all for large bridges for which MOPT does not have the capacity to build.
In view of the delays, MOPT works on bridges

The hierarch assured that the strategy involves progress with works on bridges, both bailey and permanent bridges. Castro said that Route 1856 requires 13 bridges of which MOPT placed piles on 4 of them. The National Roadway Council (CONAVI) is also participating in repair of more than 10 bridges on access roads for which piles and other baileys are already placed and should be installed by March.

ANNEX 18

"Solis Commits to Finishing the Trail", *Diario Extra*, 6 May 2014 (http://www.diarioextra.com/Dnew/noticiaDetalle/231053) (excerpts)

SOLIS COMMITS TO FINISHING THE TRAIL

In a meeting with Chinchilla

Tuesday, May 06, 2014

After holding a meeting with President Laura Chinchilla, *the President-elect, Luis Guillermo Solis committed himself to finishing the border trail interrupted by accusations of acts of corruption.* Solis upheld that it is a priority and that control problems faced by the project must improve.

The President-elect also *committed to maintaining distance with Nicaragua and to monitor the disputes under study in the International Court of Justice in The Hague.*

ANNEX 19

"Trail Will Be a Project for the Next Government", *La Prensa Libre*, 21 February 2014
(http://test.prensalibre.cr/nacional/99093-trocha-sera-proyecto-de-proximo-gobierno.html)

“TRAIL” WILL BE A PROJECT FOR THE NEXT GOVERNMENT

Friday, February 21, 2014 00:00

Despite the importance that government authorities said Route 1856 has, better known as NAC2-2-TROCHA “border trail”, the Chinchilla Miranda Administration will not be able to finish any of the five sections finished and the upcoming government will be responsible for finishing this roadway.

“At this time, we are generating the first phase of the designs; as of a few weeks ago, there is a contractor working and this is important because we overcame the barrier that prevented us from hiring”, said Pedro Castro, Minister of Public Works and Transportation (MOPT for its Spanish acronym).

The Executive Management of the National Roadway Council (CONAVI for its Spanish acronym) informed that they finished receiving offers for the entire design of the route and this will be the only process to advance before President Laura Chinchilla delivers the presidential sash to the next President.

The Government had stated that it would leave at least two of the five sections that make up the road, but this was dismissed by CONAVI.

“The route is divided into five sections, namely: Los Chiles-Pocosol, Pocosol-Infiernillo, Infiernillo-Boca San Carlos, Boca San Carlos-Boca Sarapiquí and Boca Sarapiquí- Delta. Sections 1 and 2 were expected to progress; nonetheless, procurement processes did not obtain the expected response and the lack of offers delayed the procedures to a great extent”, indicated CONAVI.

This means that the design for Section 1 will be ready by May and the total design for September 2014, i.e., when the new government is in place.

The road is not currently passable; there are sections that are being used, mostly in the areas with more economic activity, but the works underway are minor and complementary to conservation.

“There is a central portion, particularly section 35, which did not advance; it was never passable and is disabled, but the first 40 or 50 km at each end is rather passable and this is what is receiving maintenance”, said Castro.

He also stressed that they expect to leave the modular bridges under placement and to deliver construction of those designed by the Ministry with beams and piles.

ANNEX 20

"Visit by the President Two Days Before Delivering the Command",
La Nación, 6 May 2014
(http://www.nacion.com/nacional/Chinchilla-disculpa-vecinos-trocha-fronteriza_0_1412858873.html) (excerpts)

VISIT BY THE PRESIDENT TWO DAYS BEFORE DELIVERING THE COMMAND

Laura Chinchilla apologizes to neighbors along the border trail

May 6, 2014

The President of the Republic, Laura Chinchilla, apologized this Tuesday to the inhabitants of the villages surrounding Route 1856, known as the Border Trail, which was presented as one of the fundamental projects of this government and remained unconcluded due to accusations of corruption and construction failures.

"I could not end my governance without visiting one of the many towns along the road parallel to the San Juan River, first, to apologize for the events relating to that project", she said when referring to the problems in finishing the 186 kilometer roadway, which would run parallel to the San Juan River on the border with Nicaragua.

During the brief meeting, *Chinchilla also announced that redesign of the road and installation of ten bridges is already awarded with a budget from the National Emergency Commission (CNE for its Spanish acronym). "Works are underway".*

The budget involves *¢15. 299 million, of which ¢2.479 million are allocated for construction of six buildable bridges over Isla Chicha River at Los Chiles, Cureña, Cureñita, Tambor Rivers and over Trinidad and Barbudo Creek Spouts, all at Sarapiquí, Heredia Canton.*

ANNEX 21

“Works on the Trail Paralyzed while Waiting for Designs and Modular Bridges”, *crhoy.com*, 10 July 2014 (http://www.crhoy.com/trabajos-en-la-trocha-se-paralizan-a-la-espera-de-disenos-y-puentes-modulares/)

WORKS ON THE TRAIL PARALYZED WHILE WAITING FOR DESIGNS AND MODULAR BRIDGES

July 10, 2014 at: 12:00 AM

REBECA MADRIGAL

The border trail receives few visits nowadays… works required to turn the trail into a roadway have not yet begun despite the fact that the National Roadway Council (CONAVI) has 16 million Colones to invest this year.

The President of the Republic, Luis Guillermo Solis, recently toured this route and discovered that <u>much still remains to be solved</u>: passageways almost taken by the vegetation, impassable and narrow road spans, as well as evidence of the lack of planning of the initial tasks.

According to Giselle Alfaro, Supervisory Engineer at CONAVI, for now, road works do not advance because they are waiting for the design of five stretches of the route that are in the hands of CACISA and IMNSA companies. The design for the first span will be ready until this coming December, which covers the stretch from Los Chiles up to Pocosol. The total cost for these designs is ₡1.250 million.

The roadway construction cartels will then be designed. For now, it is not clear whether it is necessary to expand the route or how the drainage system will be. This will be defined once the designs are ready.

The previous administration awarded the purchase and installation of modular bridges that would set up in their sites in the next few weeks. This is an investment of approximately ₡2.479 million.

The National Laboratory for Materials and Structural Models (LANAMME) also visited the area a few months ago and made in situ recommendations to expand the lanes and further define the path; yet, the Engineer was not aware of those recommendations and assures that they never reached her door. The Minister of Public Works and Transportation, Carlos Segnini, endorsed them at that time but apparently, nothing was agreed.

The Engineer said that the trail project is “ambitious” and requires more planning and investment, but especially time, although she did not discard that it may be completed during the Solis-Rivera administration.

ANNEX 22

Alberto Cabezas, Border Trail Case, published 4 June 2014
(http://revista-amauta.org/2014/06/caso-trocha-fronteriza/)

BORDER TRAIL CASE

Published on: Wednesday, June 4, 2014

By: Alberto Cabezas

Founder: *"Fundación Mundial Déjame Vivir en Paz"*

On May 16th we sent a letter to Luis Guillermo Solis, requesting that if the government wished to continue building the border trail road, it would need to do so within the legal framework and with due supervisory oversight.

In the year 2003, I participated in the *Lapa Verde Festival* held at *El Castillo de Nicaragua*. At that time, the event was organized by Carlos Manuel Rodríguez (then head of Costa Rica's Environment and Energy Ministry) in collaboration with the Minister of MARENA (Spanish acronym for Nicaragua's Ministry of the Environment and Natural Resources). During this festival the importance of the biological corridor was explained to journalists, and today said corridor stands partially damaged.

We were pleasantly surprised to be in such place on May 22nd.

We do not regret and reiterate our complaint, filed through a remedy for protection (amparo) of the border trail, which is now more evident; however, the previous government managed to confuse the media through manipulation.

The remedy for protection was introduced on December 13th of 2011, initially intended to consult with various Costa Rican organizations and verify compliance with the legal parameters set forth in Law 7600 (which includes regulatory procedures for bidding and contracting processes not complied at the time construction began); these consultations also aimed to ensure the environment would not be harmed, given there was no environmental impact study for the project.

Later on December 22, 2011, our institution petitioned the Fourth Courtroom to annex a document to the remedy for amparo inviting court judges to perform visual inspections and a hearing between the parties involved. We informed in the annexed document the completion of technical studies in the area affected by the road. Said studies advised of the need for a bidding process for the road's construction and advised of the crucial need to involve the communities, municipalities and interested organizations in order for them to be acquainted with the project.

"That to deny communities their participatory rights, creates vacuums in their ability to control and supervise their resources"; "the foundation I represent finds it imperative that judges witness a series of violations to the principles and constitutionally granted rights, which took place at the onset of construction of the road in question".

On January 26th of 2012, we called to the attention of the Fourth Courtroom the fact that when a rural road is built according to plans, the design considers factors such as circulation speed, in turn defining traffic flow, types of trails, radius measures for horizontal transition curves as well as vertical transition curves, the edges of the embankments, resting angles for the soil (to prevent landslides), drain systems, diametrical congruence between the size of drains and their flow capacity. All of this presumes calculated design, description of the different bids with their respective technical and environmental specifications, aside from specifically describing the quality of the work to be performed. This would also include defined means for constant topographic supervision, ensuring the road is built to meet the engineering standards for which it was designed.

Of the disseminated images we have seen of this rural road, none show topographic teams supervising the construction sites. What is worse, the images indicate the lack of planning and the speed with which the construction is getting done, risking the quality and durability of the road. For example we have observed: unmeasured cuts and almost vertical soil embankments in areas of rain deposits, which during heavy rainfall can result in landslides; drain pipes displaying significantly smaller diameter in relation to their respective water ways' flow and characteristics; many drain pipes are lacking support foundations made from select material to prevent them from shifting; among other observations.

On December 22, 2011, our institution warned the Constitutional Court of the potential effect on the road's useful lifespan, which is detrimental to our public resources, belonging to the people of Costa Rica. "(…) Due to high environmental sensitivity of this niche, a rural trail produces greater long term impacts, provided the road's surface is made of select material (ballast) and dust emissions will increase, accelerating sedimentation". Also, terrain instability will increase due to both cut and fill of embankments. This is a serious problem because these are built on the edge of the river bank. There was no precaution to separate the roadway's course from the river's edge and create a buffer zone between the road and the river in the event of a landslide (which, if it does occur, would bear irreparable damage).

Another important aspect to consider is that many sectors of the road present flood risks resulting from conditions created by using transverse embankments on trough shafts. This generates the effect of a damn, when the dimensions of transverse embankments retain surface flow, as previously explained. This is a severe problem to be kept in mind because more than 80% of surface flow feeding the river after El Castillo flows from the Costa Rican basin.

Another already visible impact is the alteration of the surface drainage. This alteration may arise due to the layout of the surface drains of embankments and platforms that can artificially carry surface flow to the naturally occurring positions. The mouths where surface drains flow can create areas of erosion by means of preliminary flow contribution. Altering surface drainage affects vegetation, the river, aquatic fauna, navigation, etc.

No less important are those called cumulative impacts, growing over time and manifesting effects over the long term. Some of these impacts are changes in soil use within the biosphere reserve, because increasing access from our territory expedites the process of changing the uses of soil.

From any point of view (engineering, environmental and social), this rustic road (unplanned rural pathway), required detailed study in order to mitigate and correct many impacts that are now occurring and threatening with significant future damage. It is our opinion that no emergency, except cases where humans life is in danger (which is not the case) justifies now days, an environmental risk such as the one posed by this project as a consequence of not having conducted necessary studies to prevent processes that at this point, are very difficult and costly to correct.

On February 3, 2012, we introduced another note in the remedy for amparo, where we argued: “It is necessary to mitigate and adapt any aspects of the construction to guarantee that the infrastructure of the road meets all conditions”. “Concerning this matter, we do believe the embankments do not display the required support angle for the material they are made of. Some embankments show inclinations close to 90 degrees, so they will not have any vegetation or geo-net to prevent landslides.” “It is a fact that Costa Rica’s Government didn’t even carry out a traffic flow study for the road, a crucial element to justify executing this type of project and the degree of service to be provided in order to make efficient use of government resources”.

ANNEX 23

"Accident in Chaclacayo: Rimac river fuel spill causes concern among local residents", *El Comercio*, 31 December 2013 (http://elcomercio.pe/lima/sucesos/accidente-chaclacayo-derrame-combustible-al-rio-rimac-preocupa-vecinos-noticia-1680548)

Accident in Chaclacayo:
Rímac River fuel spill causes
concern among local residents

(VIDEO)

A truck that fell from the Los Ángeles Bridge at km 27 on the Central Highway was carrying 3,000 gallons of fuel.

The oil spill from the truck that fell into the Rímac River in Chaclacayo in the early hours of this morning has puts residents near km. 27 of the Central Road in a state of alert.

The trailer fell into the Hablador River from the Los Ángeles Bridge […] last night and caused the death of the driver, Joel Widin Mejía Cáceres.. The body was recovered by police from inside the overturned vehicle.

A brother of the victim came to the site of the accident and informed that all of Mejía Cáceres' family lives in Huancayo, but that they will be traveling to Lima for the funeral.

He said that the deceased was an experienced driver and that, before the accident, the tanker had been loaded with about 3,000 gallons of fuel in La Pampilla. This is precisely what is worrying the inhabitants in the spill zone, situated between Chaclacayo and Chosica, since the tanker was split open during the impact, allowing the fuel to flow into the river.

ANNEX 24

“OEFA assesses impact of oil spill in the Rimac River”, *Mining Press,* Edición Perú, 1 February 2014 (http://www.miningpress.com.pe/nota/250217/oefa-evalua-impacto-de-derrame-de-petroleo-en-el-rio-rimac-)

OEFA ASSESSES IMPACT OF OIL SPILL IN THE RÍMAC RIVER

Fuel spill in the Rímac River is now being evaluated by the OEFA

WEB OEFA

Technical staff from the Environmental Evaluation and Control Agency – OEFA – are carrying out an environmental evaluation following the fuel spillage in the Rímac River at km. 27 of the central highway in Chaclacayo, caused when a fuel tanker owned by Consorcio GyG E.I.R.L. fell into the river.

A specialized OEFA team is taking samples. The tanker was carrying an estimated 3,000 gallons of fuel, which was transported from the La Pampilla Refinery to a service station in Huancayo. So far the company has not taken any action to mitigate the impact of the spill, so the iridescent fuel slick is still visible in the river.

From a technical and safety point of view, fuel transportation by road is controlled by the State Energy and Mining Investment Regulator OSINERGMIN, which checks contingency plans. The OEFA's function is to control the environmental impact caused by incidents like this.
The results of the samples taken by the OEFA's technical staff will be ready within seven days.
Tanker carrying 4,000 gallons of fuel falls off bridge and contaminates the Rímac River

La República

Residents of three Chaclacayo townships were affected by the contamination of a section of the Rímac River, following a 4,000-gallon fuel spill caused when a tanker truck fell to the riverbed from the Los Angeles Bridge.

The Police warned the Lima Water and Sewerage Service Company so that it could close the sluices of La Atarjea water treatment plant to counteract the effects of the dangerous chemical spill.

The accident occurred shortly before midnight on Monday, but it was not until 1:30 a.m. yesterday that Emergency Squad personnel and firefighters managed to plug the holes in the tank to prevent further fuel leakage. The rescuers took another two hours to reach the driver of the vehicle, Joel Widin Mejía Cáceres (41), who had died trapped in the cab.

The truck (number plates W2T-917) had left Callao and was taking fuel to Huancayo. For reasons that are now being investigated, the driver got confused when crossing the Los Angeles bridge, located at km. 27 on the Central Highway. After knocking down a long stretch of the bridge railings, the out-of-control vehicle plunged from about 20 meters high and landed upside down in the river.

Residents of the townships of La Perla, Grau and Los Angeles are the hardest hit. Residents of the first two, which are on the banks of the Rímac, often take water from the river for preparing food, washing clothes, or bathing. As of last night the authorities had still not been able to remove the truck from the riverbed.

ANNEX 25

"Oil spilled into the Villalobos River", *La Nación*, 19 June 2012 (http://www.lanacion.com.co/index.php/noticias-judicial/item/156017-petroleo-cayo-al-rio-villalobos)

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OIL SPILLED INTO THE VILLALOBOS RIVER

Written by editor

A tanker truck carrying 240 barrels of crude oil to Neiva, overturned, and the fuel reached the Villalobos River. A burst tire caused the vehicle to overturn.

A tanker truck carrying 240 barrels of crude oil to Neiva, overturned, causing the fuel to reach the Villalobos River. A burst tire caused the vehicle to overturn. RODRIGO ROJAS GARZÓN **LA NACIÓN, PITALITO**. An environmental emergency was caused by a crude oil spill that reached the Villalobos River in the Putumayo, after a tanker truck carrying 240 barrels of fuel to the city of Neiva overturned. The accident happened yesterday morning at km 35 in the La Petrolera sector on the road leading from the town of Mocoa to Pitalito. The driver of the Kenworth truck (number plates OFV-966) owned by the company Transdepet y Carga Ltda. lost control after one of the front tires burst. The vehicle then overturned on a slope and into a gutter, along which the crude oil began to flow until it reached La Cristalina Creek, a tributary of the Villalobos River. "The oil slick reached the course of the Villalobos River, and began to contaminate the river basin downstream," said Carlos Facundo, who lives by the side of the Villalobos tributary. According to first reports, the tanker truck was carrying 240 barrels of oil, of which Transdepet managed to retrieve 40, while the remaining 200 fell into the river. "The environmental damage that has been caused is very serious and irreparable, because an entire river ecosystem has been affected...," said the local resident. He claimed that officials from the Regional Autonomous Corporation of the Department of Cauca went to the site and left minutes later. "In the same way as they came they left without following up on the contingency plans to address the environmental emergency...," said Carlos Cabrera, who has also been adversely affected by the accident. According to residents in the sector, in the last month three vehicles of this type have overturned, causing similar environmental emergencies, and the authorities have failed to implement the controls on the transportation of this type of fuel, which generates high levels of contamination. “To keep control of the situation and of the numerous residents of the places where the emergencies occur, these companies pay 40,000 pesos to the people who have suffered adverse impacts and give them lunch for every day that they spend cleaning up the ecological damage caused to the river. The fact is, though, that no price can be put on making up for this kind of damage to the environment and the communities,” said Cabrera. Representatives of Transdepet y Carga Ltda. declined to comment on this matter to LA NACIÓN. Photos: Rodrigo Rojas

(Image) The tanker truck that overturned while carrying 240 barrels of crude oil caused an environmental emergency.

(Image)The fuel reached the Villalobos River.

ANNEX 26

"Ombudsman investigates mining company spillage into River",
Los Andes, 26 August 2009
(http://archivo.losandes.com.ar/notas/2009/8/26/un-442539.asp)

OMBUDSMAN INVESTIGATES MINING COMPANY SPILLAGE INTO RIVER

A truck owned by Minera La Alumbrera spilled diesel fuel into a river in Catamarca. Local residents have set up a picket and are demanding assurances that their drinking water is clean.

An official from the National Ombudsman's Office toured the Belén River yesterday, where diesel fuel from a truck owned by Minera La Alumbrera, spilled last Wednesday the 19th.

The official, Roberto Saravia, toured the river yesterday in the city of Belén, Catamarca, where, on the 19th of this month, a truck carrying diesel fuel to Minera La Alumbrera overturned and spilled fuel into the river, prompting protests from local residents and subsequent explanations from the company.

When Saravia arrived he found that local residents had set up a blockade on Route 40 at the entry to Belén to prevent trucks from reaching the mine.

According to local media reports, after arriving at the scene he carried out a photographic survey of the oil slicks on the river bed and kept in contact with residents in order to make a report that will be delivered to the Córdoba Ombudsman, Anselmo Sella, who will decide whether to send in environmental experts to ensure that the water consumed by the area's inhabitants is free from contaminants.

ANNEX 27

"Oil spill contaminates lake", *Peru21*, 9 May 2012 (http://peru21.pe/2012/05/09/impresa/derrame-crudo-contamina-laguna-2023480)

OIL SPILL CONTAMINATES LAKE

Wednesday, May 9, 2012 | 1:52 a.m.

Much of Lake Huachucocha was left stained and smelling strongly of oil as a result of the spill of crude oil that occurred when a trailer loaded with fuel overturned on to its waters. The accident took place at km. 91 of the Antamina - Conococha Road, in Huari.

The Mayor of San Marcos, Óscar Ugarte, said that the accident had caused the death of hundreds of trout fingerlings and wild ducks, and because of this, representatives from the Public Prosecutor's Office and municipal environmental experts took water samples to determine the degree of contamination.

ANNEX 28

“Oil truck overturned near the Cruces River”, *El Mercurio Online*,
3 January 2009
(http://www.emol.com/noticias/nacional/2009/01/03/338122/camion-con-petroleo-se-volco-en-las-cercanias-del-rio-cruces.html)

OIL TRUCK OVERTURNED NEAR THE CRUCES RIVER

The truck spilled about 200 liters of crude oil in the Iñake River, 32 km north of Valdivia.

[...]

SANTIAGO. A truck loaded with oil overturned this afternoon on the Iñake bridge in the Mafil area, 32 kilometers north of Valdivia, resulting in a serious spill that has authorities and the community in a state of alert.

The accident, which occurred on an unrailed wooden viaduct located on a country road, caused about half of the 200 liters of oil to be spilled from the vehicle's cargo compartment—suitable for the transport of animals—straight into the river.

Chilean Navy personnel, police, personnel from the National Emergencies Office (Onemi), and the Valdivia Fire Service Hazardous Materials Squad are working at the site to prevent the crude oil from contaminating the waters of the Cruces River.

They are doing this because, after the truck overturned, the maximum risk was that crude oil might reach one of the region's main rivers, adjacent to the contaminated branch. Using absorbent pads, they have already managed to contain 90 liters.

The causes of the accident and the magnitude of the consequences of the oil's moving along the channels of the river are still unknown.

What was confirmed was that the spill affected some 20 tourists who were camping at the "La Islita" campsite, adjacent to where the accident occurred. However, one of the main threats is that crude oil could reach the Cruces River, where the Carlos Anwandter Nature Sanctuary wetlands are located.

The Onemi has told the owner of the location that the waters in the area will not be suitable for bathing for at least a week, and it will test the water quality from a well, which is used for drinking and cooking.

ANNEX 29

"Truck spilled 9,000 gallons of fuel into Rivers", *Enlace Nacional,*
4 February 2008,
(http://enlacenacional.com/2008/02/04/camion-derramo-9-mil-galones-de-petroleo-en-rios/)

TRUCK SPILLED 9,000 GALLONS OF FUEL INTO RIVERS

Monday February 4, 2008

(VIDEO)

A Bolivian fuel tanker overturned on the Bi-National Highway in the Moquegua region's Torata district, spilling more than 9,000 gallons of fuel, which contaminated the rivers Chiguilla and Huaracané, the major sources of the water supply for Ilo.

The municipal authorities of Mariscal Nieto Province, as well as Civil Defense personnel, moved into the area to take preventive measures. According to Civil Defense spokesman Francisco Chávez, sponges mixed with clay will be used in the cleanup operation. Furthermore, containment dikes have been installed at the inlets of the Huaracané to monitor the concentration of fuel in the river.

ANNEX 30

“Truck overturns – Sever Environmental Damage”, *La Angostura Digital*,
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(http://www.laangosturadigital.com.ar/v3/home/interna.php
?id_not=10282&ori=web)

TRUCK OVERTURNS – SEVERE ENVIRONMENTAL DAMAGE

A tanker heading to Villa la Angostura overturned in icy conditions and fell more than 50 meters into Lake Nahuel Huapi, where it spilled 10,000 liters of diesel fuel. The driver jumped out and suffered only a broken finger.

The fuel slick spread over some 700 meters of shoreline, but luckily there was no wind and it could be controlled.

The accident involved a tanker truck loaded with diesel fuel bound for the EPEN power plant in Villa la Angostura and led to severe environmental damage when some 10,000 liters of fuel spilled into Lake Nahuel Huapi.

At about 10:20 a.m. the tanker, belonging to Petrolera Plaza Huincul Argentina S.A., was being driven toward La Angostura on Route 231, when, at the 25.500 km. mark, its driver lost control after coming out of a curve and running into ice on the road.

The truck skidded for about forty yards before hitting the guard rail on the opposite verge and plunging more than 50 meters into the lake, in a fall that completely wrecked the cab.

The Renault 350 truck (number plates TSJ 299) was being driven by Juan Martin Liutti, who jumped out as at it began to fall, an action that, in view of what happened to the cab, must have saved his life. As it was, he escaped with a broken index finger on his right hand, a few grazes, and a cut on his right temple.

A motorist took the driver to the police checkpoint at Muelle de Piedra, and from there he was taken to the local hospital where he was given first aid. Later he was transferred to Bariloche because of his broken finger.

The part of the tanker that fell into the lake was carrying about 10,000 liters of fuel, while another 22,000 liters in the overturned second trailer was spilled on Route 231. Although there were no accurate figures, it was estimated last night, on the basis of information supplied by the Fire Service, that some 10,000 of the 32,000 liters were spilled over the road, the hillside and the lake.

Emergency Plan for the spill

A large slick of diesel fuel some 700 meters in length spread over Lake Nahuel Huapi. However, the calm conditions worked in favor of the contingency plan because there was no wind to drive the fuel towards the center of the lake.

The Coast Guard arrived a few minutes after noon with a small boat and divers, who put the first absorbent containment barriers in place to prevent more fuel leaking from the tanker.

Because the lake is under federal jurisdiction, National Parks, Gendarmerie and the Coast Guard took control of the situation. Later, they were joined by Neuquen province Civil Defense personnel and special teams from the oil company, who today will attempt to recover the fuel spilled in Lake Nahuel Huapi.

Emergency for EPEN

The accident involving the truck that was supposed to supply EPEN’s local plant with fuel triggered an emergency situation and the probability of power cuts in the town due to lack of fuel.

This was the warning given by the provincial power company early in the afternoon and in a recent statement from the Municipality. However, after a tanker carrying 8,000 liters of diesel fuel to a service station was diverted to the power plant, by 7:00 p.m. the risk of a power outage had been avoided.