Hydrologic, Geomorphologic and Ecologic Considerations to Ensure Ecological Integrity and Sustainable Fisheries in the Agusan River Basin

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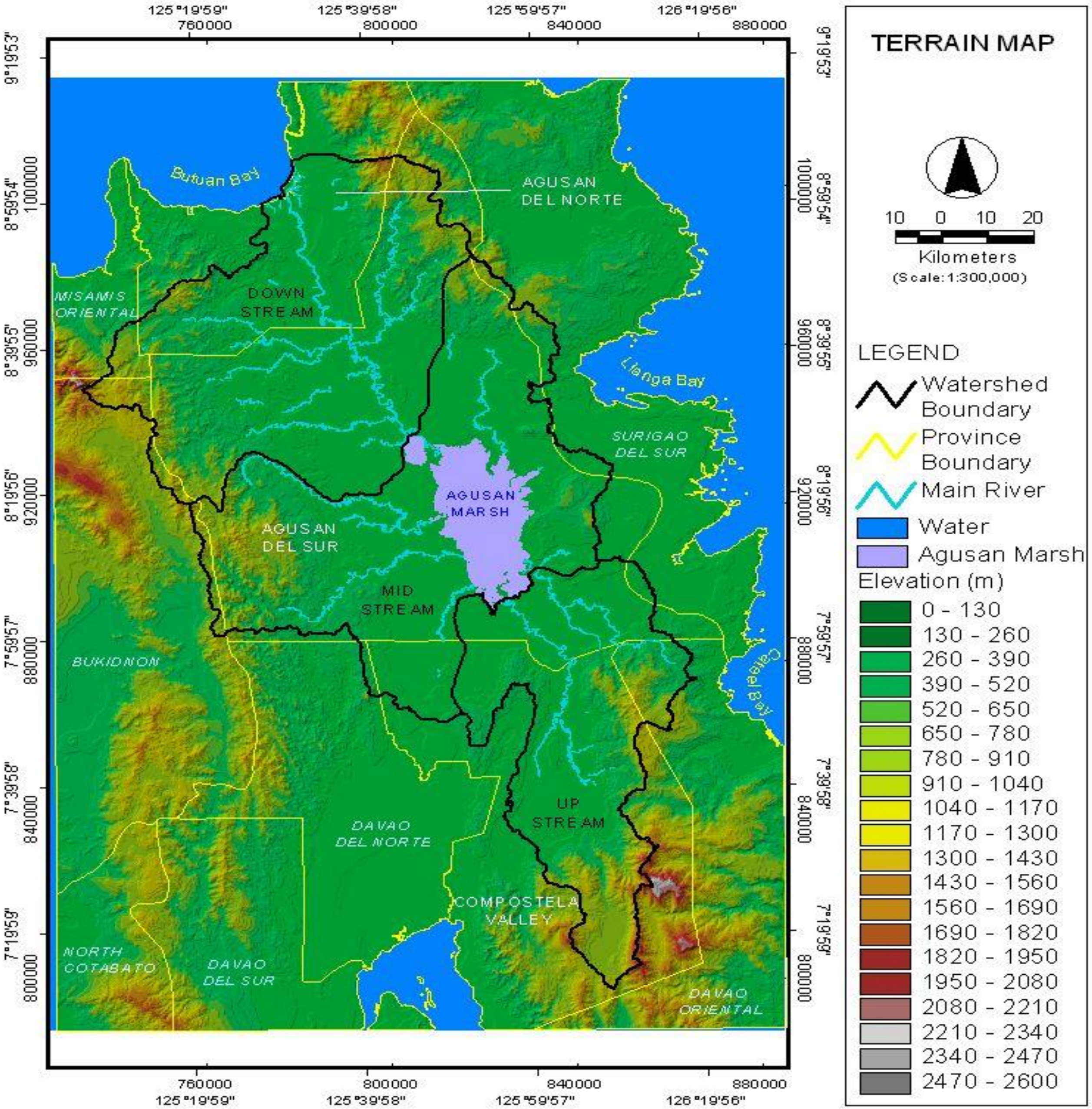
Outline of Talk

- **State of Agusan River Basin and Agusan Marsh**
- **Geomorphology and Flood Hydrology of Agusan River**
- **Existing Water Situation and Possible Impacts of Proposed Water Resources Development in Agusan River Basin**
- **Hydrologic, Geomorphologic and Ecologic Interactions**
- **Agusan River Basin Management Objectives for Sustainable Fisheries based on Hydrologic, Geomorphologic and Ecologic Considerations**
- **On Adaptive Planning and Management of River Basins**
- **Conclusions**

Agusan River Basin



(from CTI-HALCROW-WOODFIELDS 2007)

State of Agusan River Basin

- **The Agusan River Basin is under threat by ongoing and planned activities.**
- **Nearly all primary forest cover have been removed during the period of 1950-1970 resulting increase in sediment load of rivers as manifested in siltation of irrigation channels and increase in frequency of floods in the downstream area of Agusan River.**
- **Logging continues in its watersheds, legitimized by Integrated Forest Management Agreement (IFMA) permits despite the presence of pristine forests in some concession areas.**

- **Mining operations in the eastern hills of Compostela Valley are widespread with estimated annual discharges of 300,000 tons of mine tailings into Agusan River through the Naboc River that has resulted in heavy metal pollution including mercury in the water, sediments and biota downstream of these mining operations.**
- **Development plans include construction of more irrigation for certain agro-forest industries and the construction of dams and reservoirs for hydroelectric power generation and flood control that could potentially affect the ecology of the river basin.**

Agusan Marsh (Heart of Agusan River Basin)

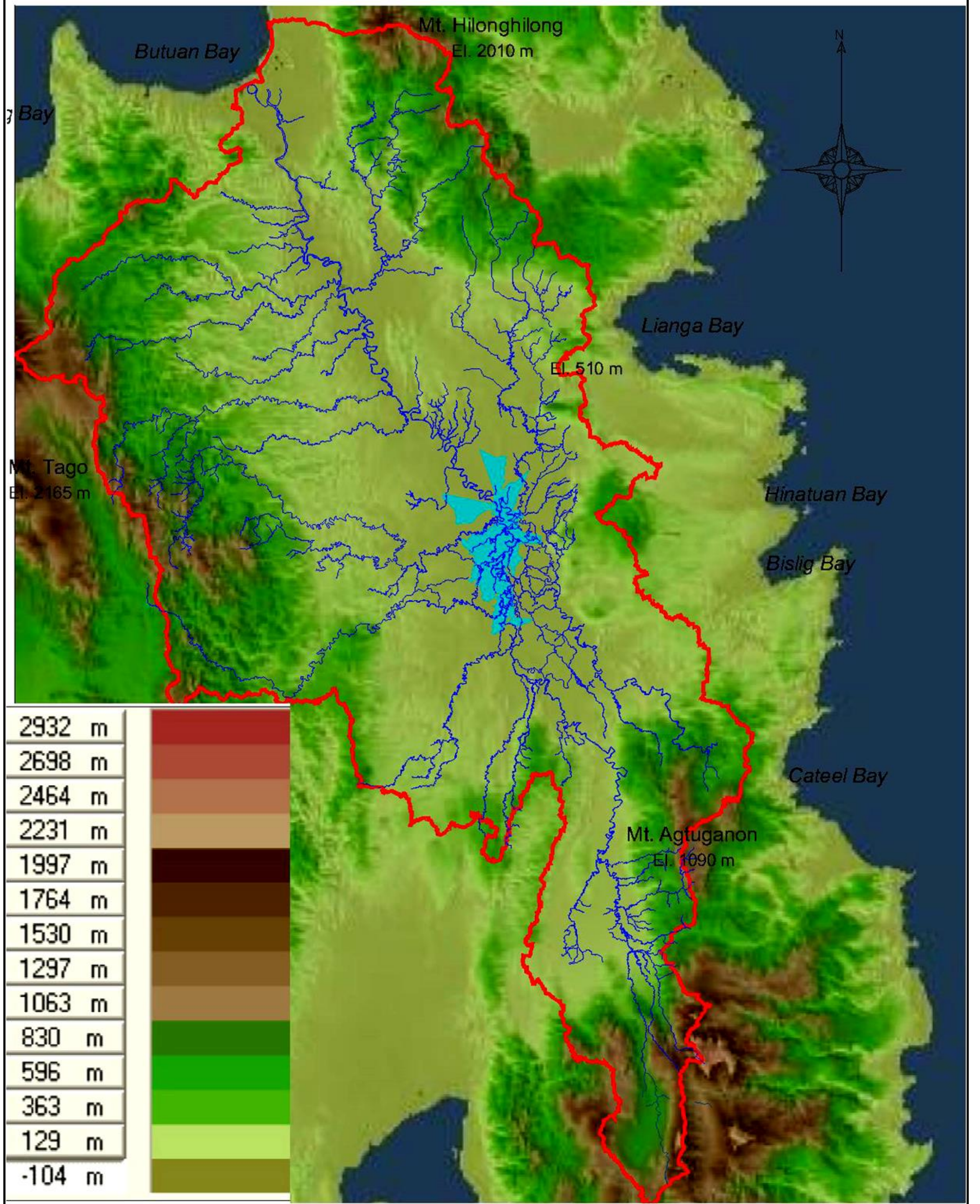
- **Agusan Marsh is an extensive flood plain covering about 19.2 sq. km.**
- **Harbors a remarkable diversity of 10 habitat types and subtypes, among them the unique and pristine peat swamp and sago palm forests**
- **Home to rare and endangered fauna such as the Asian soft-shelled turtle and 31 endemic bird species, three of which are listed as vulnerable on the IUCN Red List of Threatened Species -- *Ducula carola*, *Eurylaimus* and *Alcedo argentata***
- **The avifauna includes some 26 migratory species, making it of global significance.**

- **As one of the Philippines' ecologically significant wetlands, the Agusan Marsh was declared a protected site under the National Integrated Protected Areas System (NIPAS) in 1994, a Wildlife Sanctuary by Presidential Proclamation 913 in 1996, and a Wetland of International Importance by the RAMSAR Convention in 1999.**
- **Aside from its ecological function, it serves as a flood retention basin that protects downstream towns and Butuan City from flash floods.**
- **There are reports of planned projects to drain significant portions of the Marsh for conversion to banana, palm oil and fruit plantations.**

Geomorphology and Flood Hydrology of Agusan River Basin

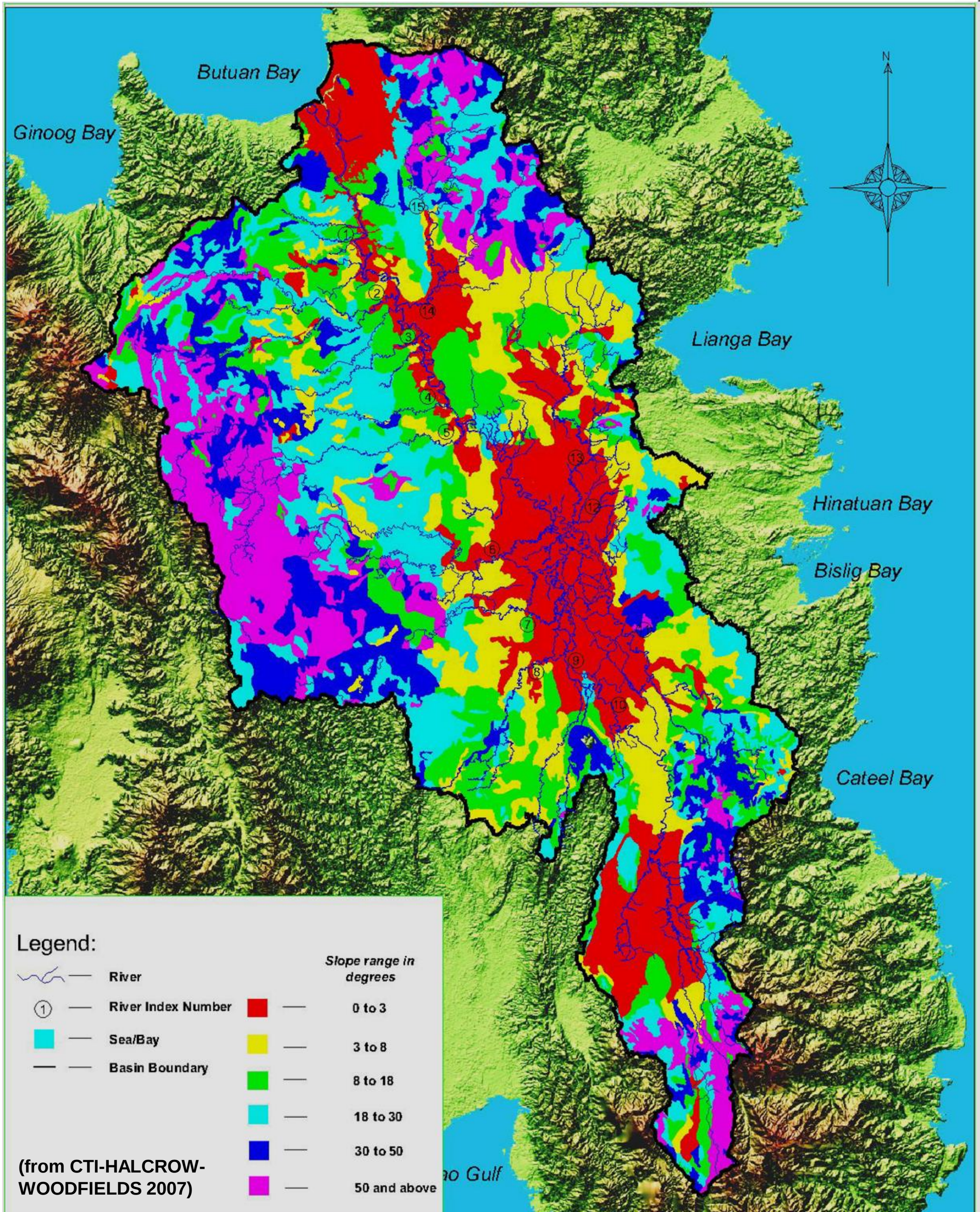
Agusan River Network

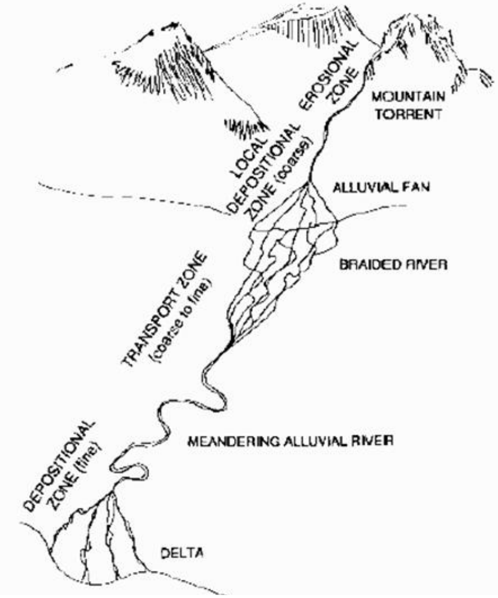
River Index Number	Sub-Basins	Catchment Area	Percent of the Basin Area
1	Bugabos	170.55	1.43
2	Ojot	924.20	7.74
3	Libang	246.56	2.07
4	Maasam	418.20	3.50
5	Kasilan	376.89	3.16
6	Adgaon	984.81	8.25
7	Kayonan	729.47	6.11
8	Haoan	746.34	6.25
9	Logom-Baobo	291.20	2.44
10	Manat	1,758.20	14.73
11	Simulao	978.38	8.20
12	Lagcogangan	159.75	1.34
13	Gibong	926.38	7.76
14	Wawa-Andanon	764.14	6.40
15	Taguibo	75.72	0.63
	Total	9,550.78	80.01
	Basin Area	11,936.55	

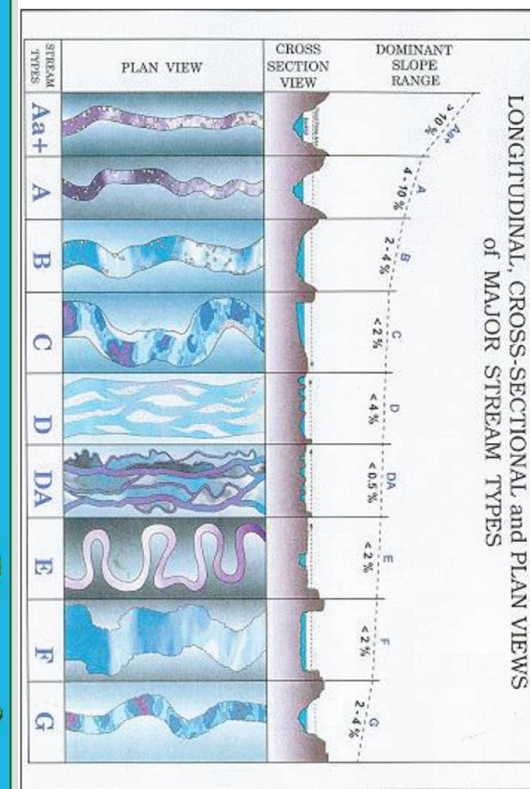


(from CTI-HALCROW-WOODFIELDS 2007)

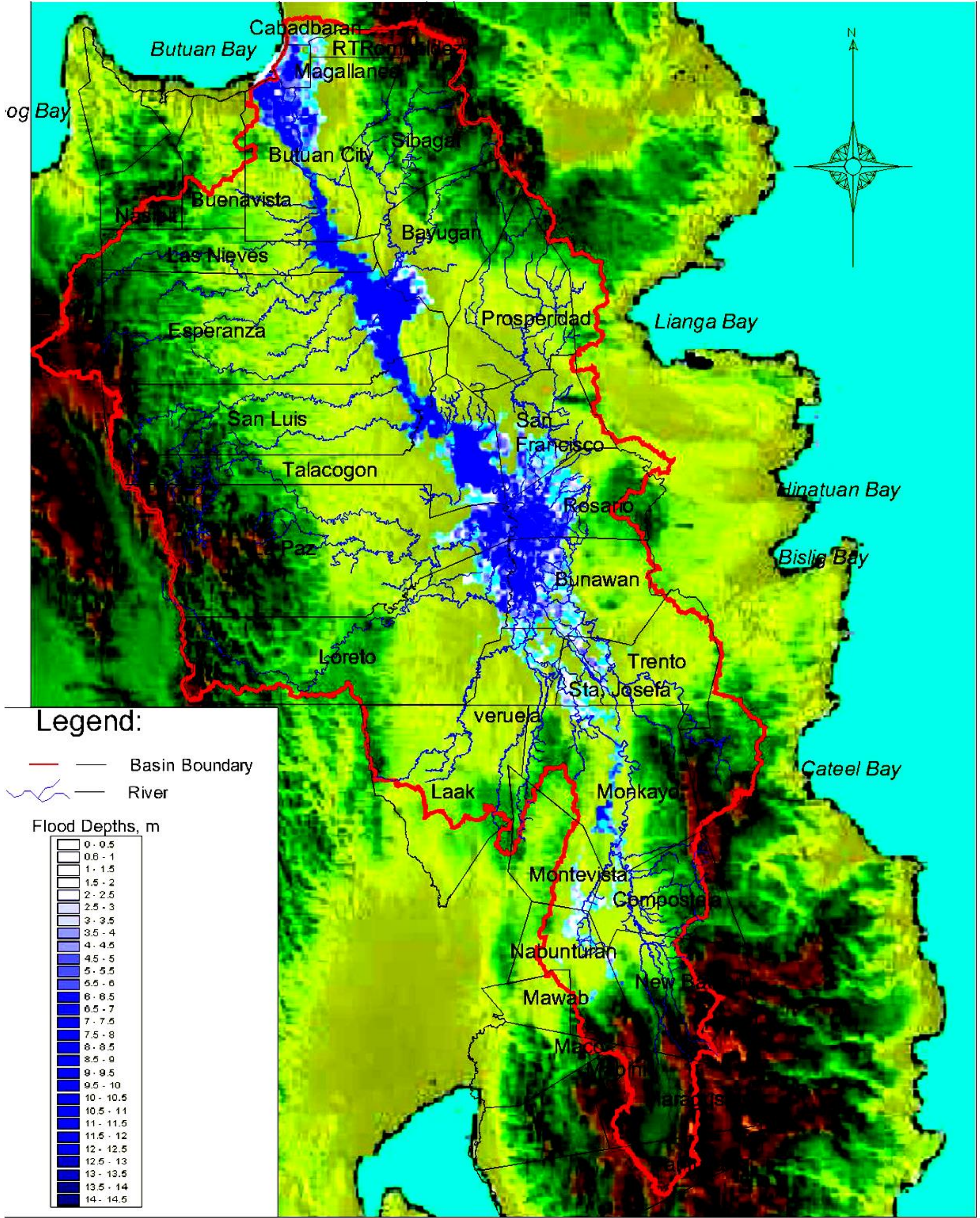
Agusan River Basin Slope Map and Stream Types







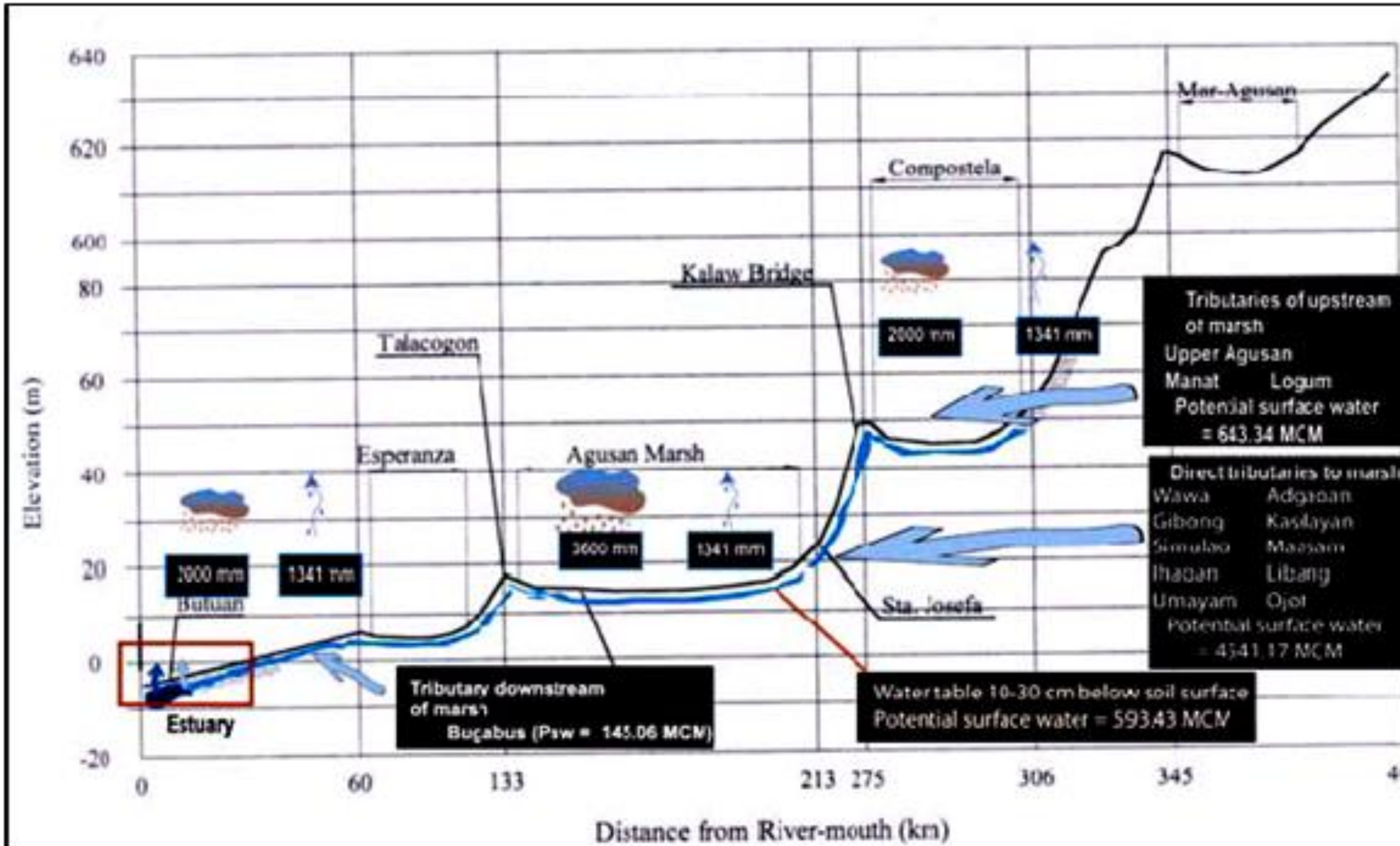
Flood Inundation Map for a 30-yr Rainfall



(from CTI-HALCROW-WOODFIELDS 2007)

Existing Water Situation and Possible Impacts of Proposed Water Resources Development in Agusan River Basin

Present water situation of Agusan River Basin and Agusan Marsh in particular (CARDBP-PMO, 2003)



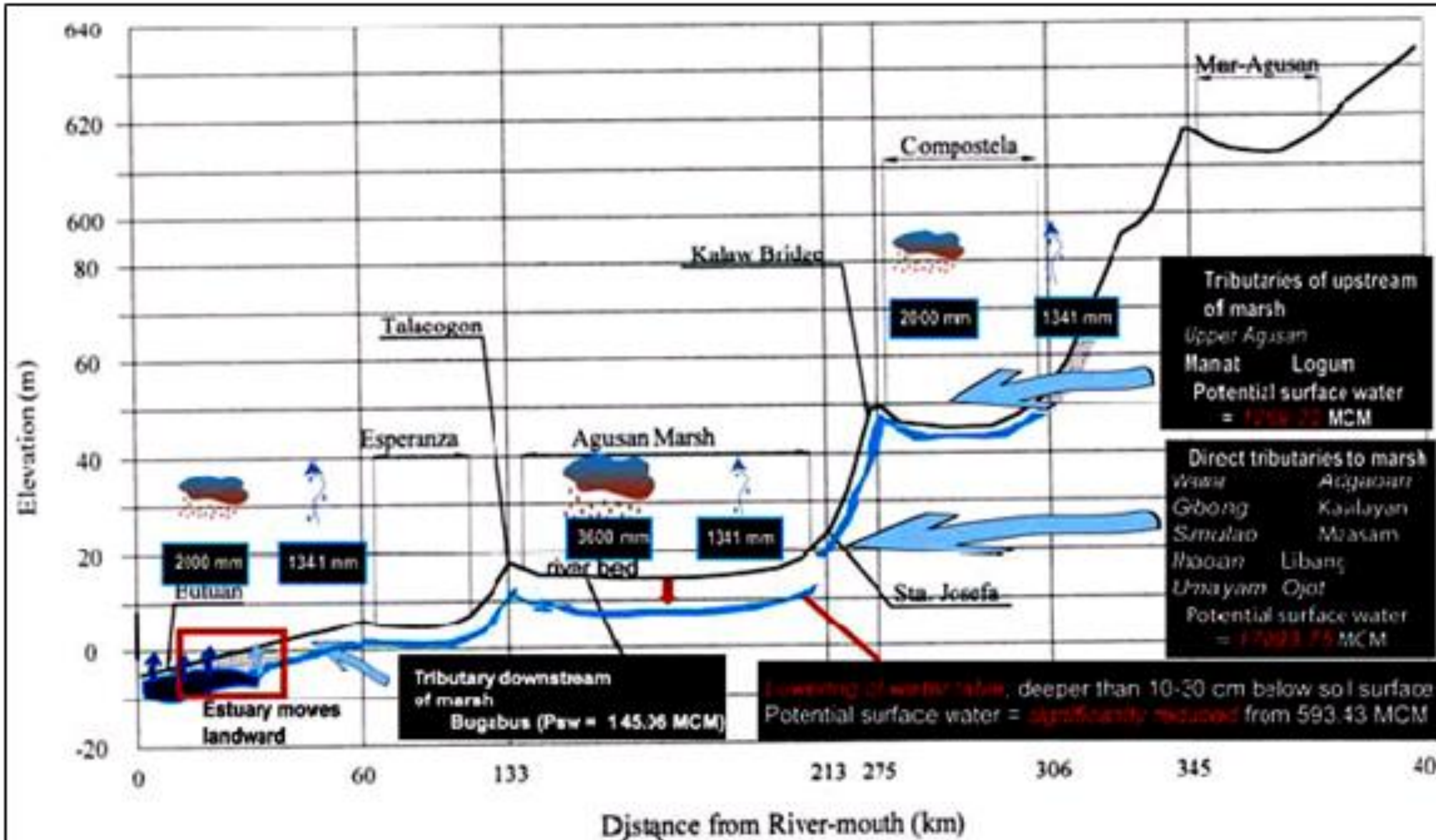
Proposed Water Resources Development in Agusan River Basin

- **Planned upstream reservoirs in the Upper and Middle Agusan River**
- **Flood control plan involving diking and river straightening in the Upper Agusan River (Compostela Valley area)**

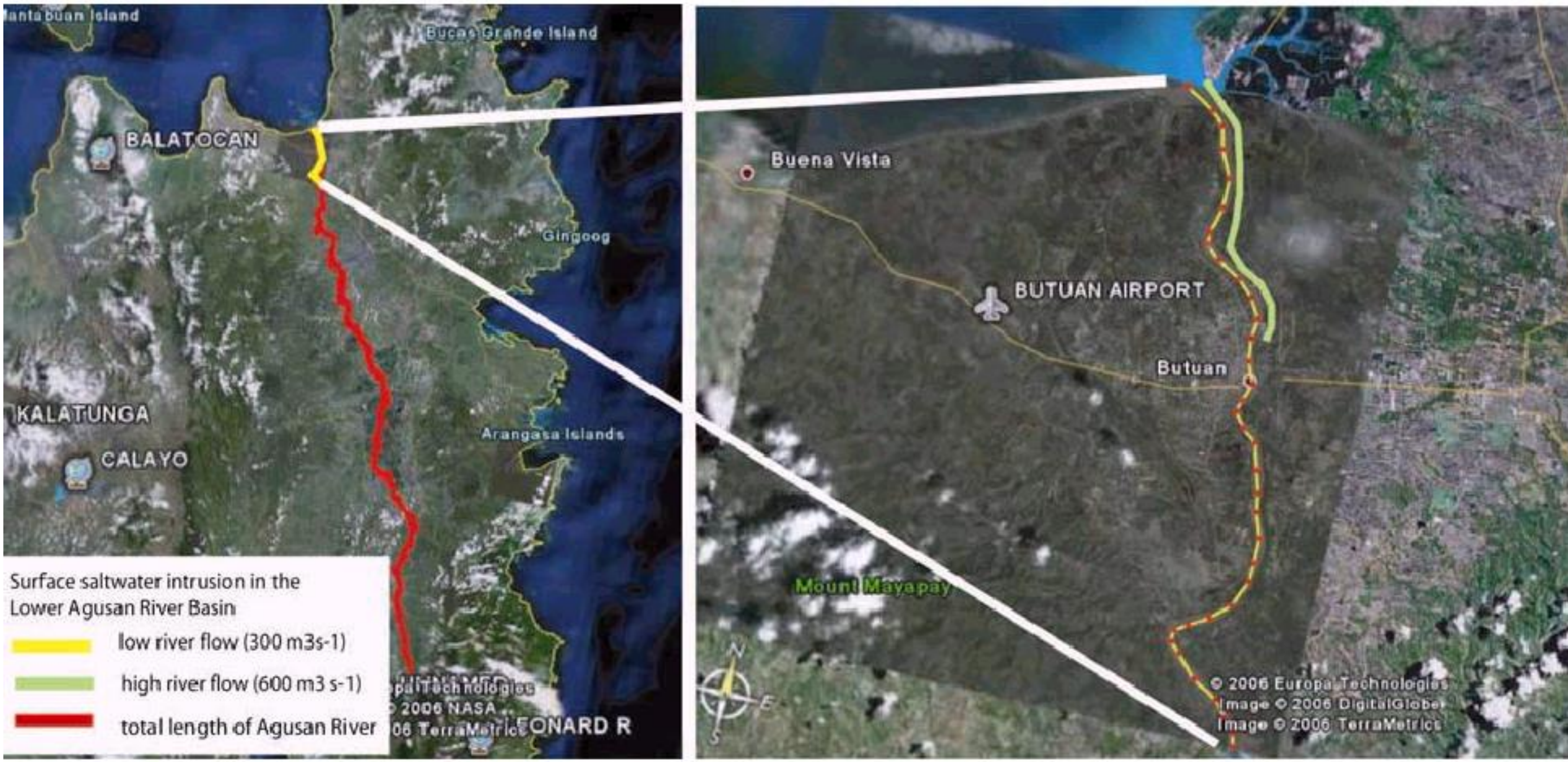
CARDBP-PMO (2003) Proposed dam constructions including characteristics of main river channels and major tributaries in Agusan River Basin.

Main Channel / Major Tributaries	River Area (Km2)	Length (km)	Slope	Potential Surface Water (MCM)	Proposed Dam Height (m)	Reservoir Storage Volume (MCM)	Power Potentials (MW)	Target Year of Operation
Upper Agusan	1570	171	´1/1900	454,12	100	1080	-	2020
Manat	196	27	´1/20	138,76	plan			-
Logum	151			50,46	plan			2015
Middle Agusan	9610	158	´1/16,800					
Wawa	1026	81	´1/60	851,47	180	6980	-	
Gibong	1269	115	´1/90	473,04	50	2540	-	2016
Simulao	997	111	´!/70	441,51	120	900	-	2017
Ihaoan	656	83	´1/140	220,75	40	700	-	2012
Umayam	782	102	´1/90	315,36	100	1250	130	
Adgaoan	983	123	´1/80	378,43	60	920	65	2020
Kasilayan	300			378,43				
Maasam	400			441,5				
Libang	280			283,82				
Ojot	805	68	´1/40	756,86	90	2700	30	-
Lower Agusan	520	21	´1/4000					
Bugabus	184			145,06				

Impacts of planned reservoirs in the Agusan River Basin and Agusan Marsh in particular (CARDBP-PMO, 2003)

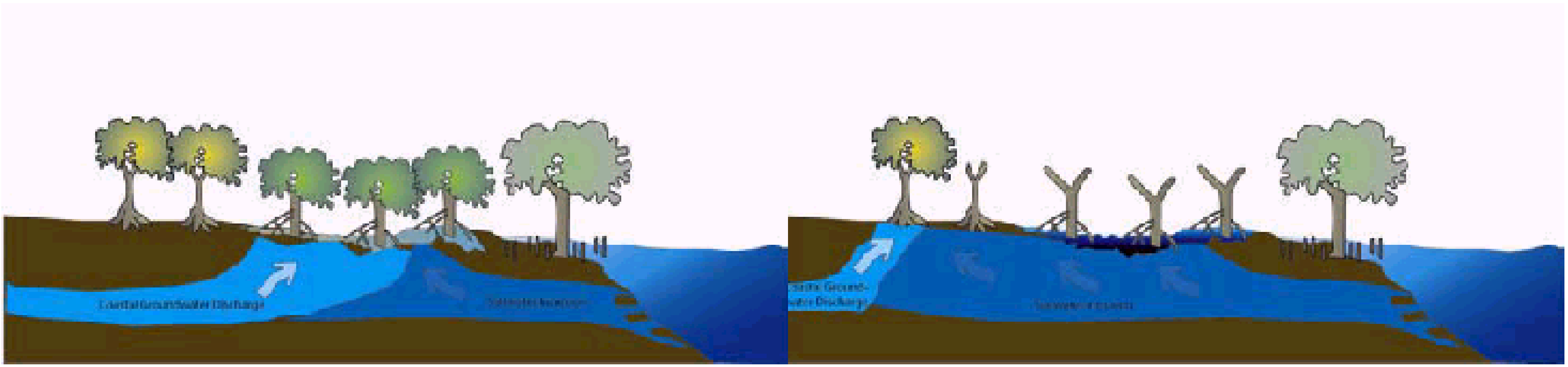


Saltwater intrusion further inland in Agusan River at Butuan City estuary if freshwater inflow is reduced



From Agusan National High School Einstein Class 1999 (web)

Adverse impact to ecosystem health of mangrove forest due to reduced groundwater recharge and flux

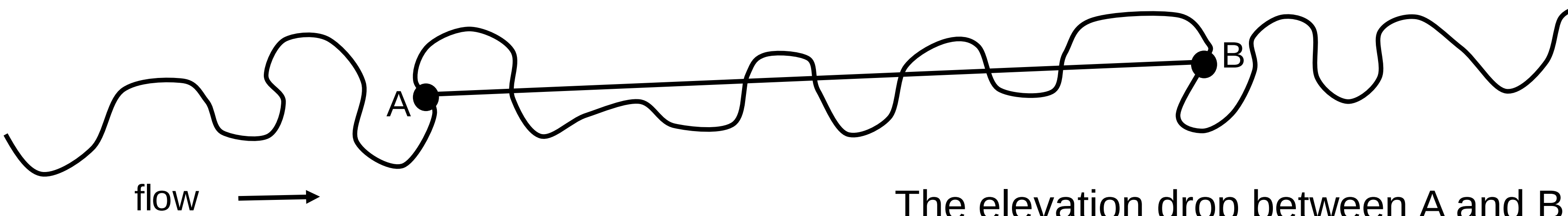


(a) (b)

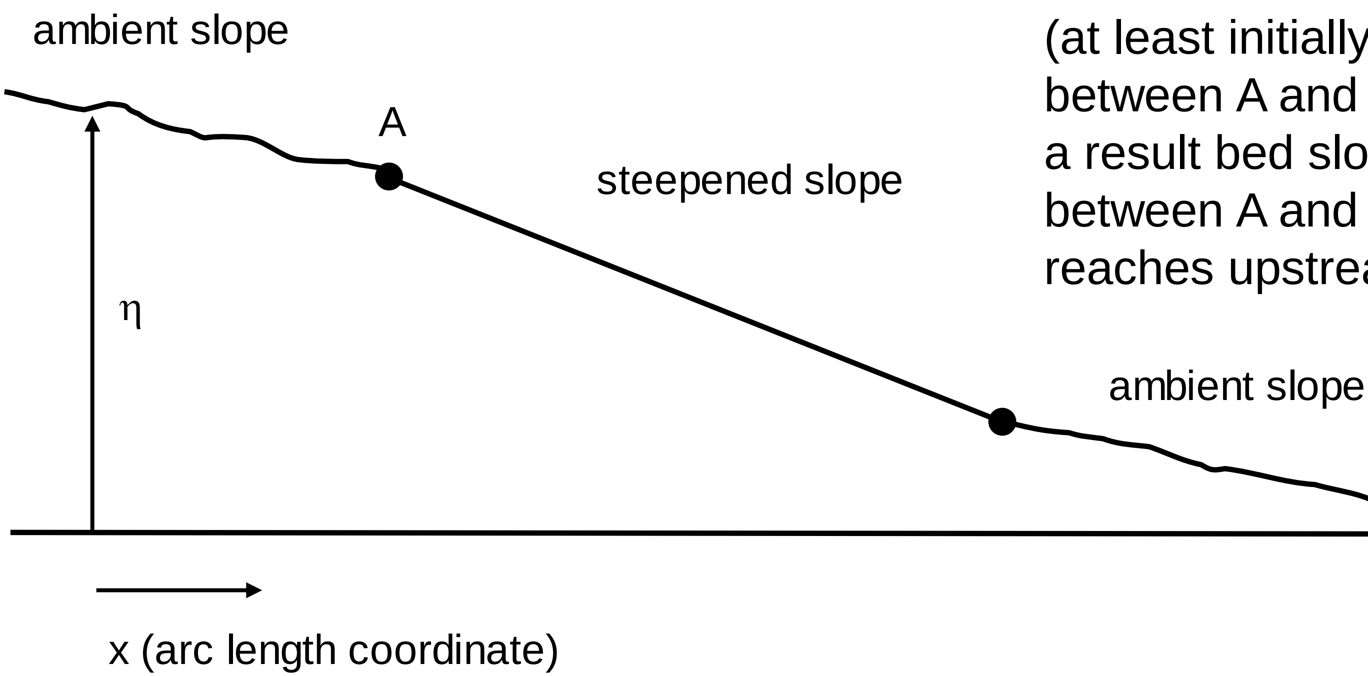
Figure 5. Influence of coastal groundwater discharge to the ecosystem health of mangrove forests. a) Normal mixing of fresh groundwater and saline water intrusion causes existence of healthy mangrove community. b) Increased saltwater intrusion landward creates zones of hypersalinity within the mangrove forest causing mangrove die-back to occur. (Graphic Source: IAN-UMCES, 2006)

RIVER STRAIGHTENING

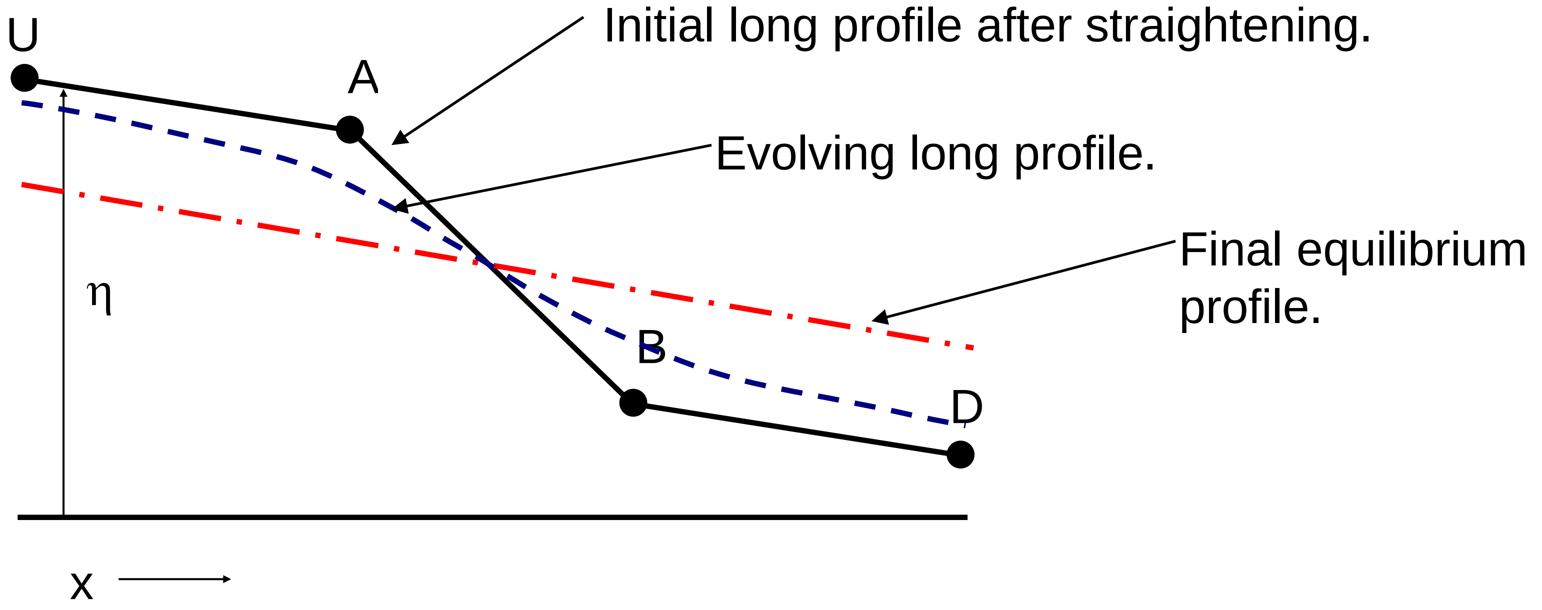
The bends between points A and B are cut off due to river straightening.



The elevation drop between A and B is the same as before straightening (at least initially), but the distance between A and B is much shorter. As a result bed slope is elevated between A and B compared to the reaches upstream and downstream.



RIVER STRAIGHTENING (contd.)



The upstream part of the reach must degrade and the downstream part must aggrade until a new equilibrium profile is established.

The above 1D picture is a simplified version of reality: too much aggradation downstream will cause the river to avulse (jump channel).

Hydrologic, Geomorphologic and Ecologic Interactions

- **The geomorphology and hydrology of a basin interact with each other since the morphology of the river system influences the shape and magnitude of the basin hydrograph while the landform or morphology of the river system is shaped by the hydrologic or hydraulic flow regimes of the basin. In particular:**
    - **High flow regimes are generally responsible for removing or mobilizing sediments by erosion while the low flows promote deposition of sediments.**
    - **During high flows, rivers can flush fines and sand in the streambed gravel matrix.**
    - **The geomorphologic features of the river such as shape, slope and sediment size dictate the type of sediment load in the river as well as stability in terms of being straight, meandering or braided.**

- **Ecology interact with basin hydrology including river hydraulics since river ecology in terms of biotic structure (i.e., species, composition and communities) and life cycles of the flora and fauna, highly depend on the seasonal variations of:**
  - **river flow especially its dilution effects on water quality,**
  - **channel velocity distribution,**
  - **frequency of bankfull-discharge condition or floodplain-river interaction,**
  - **floodplain recession rates,**
  - **water residence times, and**
  - **temporal and spatial frequencies of floodings.**

- **River geomorphology in terms of bathymetric features, sediment loads and water-sediment balance influences ecology in terms of biogeography as well as the birth and survivability of aquatic flora and fauna.**
- **For example, the spawning behaviour of certain fishes depend on the location in a river reach where they deposit and fertilize eggs in riffles or cobble bars and they rest and feed in pools (in a riffle-pool sequence) between spawning forays.**
- **Finally, ecology can affect geomorphology in terms of bioturbation such as burrowing organisms that cause resuspension of sediments in lakebeds or streambeds.**

Note on temporal and spatial scales of fluctuations of the various processes involve in the hydrologic, geomorphologic and ecologic interactions. (Examples)

- **Flood flows with accompanying high sediment loads can abruptly change the river morphology in a few hours or few days. This is in contrast to geomorphologic changes due to bioturbation by burrowing organisms, which could take several months or years to result in significant river or lakebed changes.**
- **The impact of the disappearance of wetlands due to river water diversion or climatic drought take several years to realize that the wetland flora and fauna are also disappearing.**

Agusan River Basin Management Objectives for Sustainable Fisheries based on Hydrologic, Geomorphologic and Ecologic Considerations

Key considerations in river basin management objectives for sustainable fisheries based on hydrologic, geomorphologic and ecologic regimes

1) the integrity of the system, including its stability and resilience, are maintained if key structural characteristics, such as availability of refuges, continuity of river and floodplain habitat, river flow, sediments and morphology interact; and,

2) maintenance of natural hydrologic regimes with its associated geomorphologic and ecologic interactions is a major factor in maintaining and sustaining a naturally functional ecosystem.

Thus, the specific river management objectives suggested here are as follows:

1. **Continuous flow with duration and variability characteristics comparable to historical records.** ***[This particular criterion is designed to maintain favorable dissolved oxygen regimes during late summer months; provide non-disruptive flows for fish species during the reproductive period; and, restore temporal and spatial aspects of river channel habitat heterogeneity.]***

2. **Average flow velocities is say, 60 percent of the flow area is between 0.2–0.6 m/sec, when flows are contained within channel banks.** ***[This protect river biota from excessive flows, which could interfere with important biological functions such as feeding, and reproduction and that the flows lead to maximum habitat availability.]***

3. **Stage-discharge relationship that results in overbank flow along most of the floodplain when discharges exceed say 300-400 m^3/sec.** ***[This is important to establish important physical, chemical and biological interactions between river and floodplain. In particular, this reestablishes connectivity and allows transport of nutrients from floodplains to the main river contributing to higher fish productivity.]***

4. **Stage recession rates on the floodplain that typically do not exceed say 0.3 m/month.** ***[Slow drainage is important during biologically significant time period such as wading bird nesting and that excessive recession rates can lead to fish kills. In fact, rapid recession rates may cause drowning of species and may trap and expose organisms to desiccation.]***

5. **Stage hydrographs that result in floodplain inundation frequencies comparable to historical hydroperiods (say, in the last 50 years or so), including seasonal and long-term variability characteristics.** ***[To maintain seasonal wet/dry cycles in floodplain is considered to be most important ecological feature of a wetland.]***

   Related to this criteria is the flood pulse concept which has the following benefits to fish production ***(Rommel Maneja, 2007):***

   - **Before flooding periods, adult predators swim upstream and spawn eggs and larvae that later drift downstream to encounter prey to feed on resulting in high fish catches.**
   - **Flooding leads to prolong food availability thus extending the growing season and leads to higher biomass production.**

An Example: Candaba Swamp as Detention Pond for Ecological and Flood Control Purposes

The Candaba swamp serves as a habitat for local and migratory birds thereby an ecotourism site. It also acts a natural flood detention basin during the wet season.

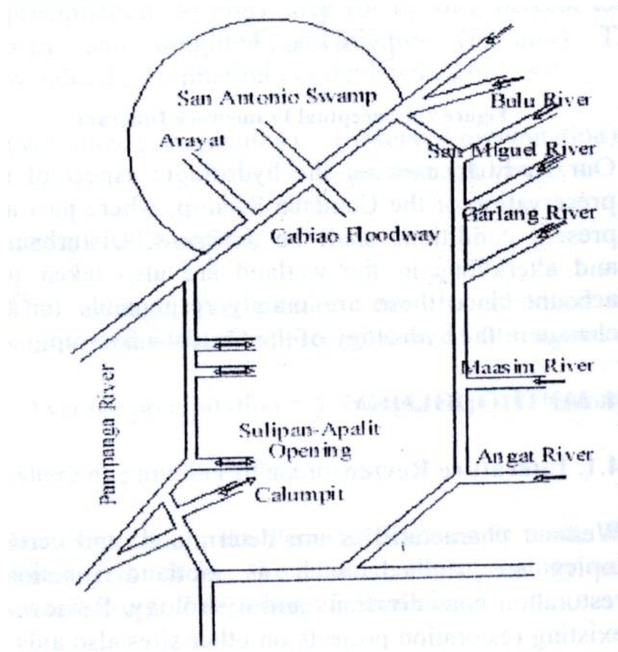


Table of Percent of time the area (highlighted) is flood inundated

Month	100%	85%	65%	50%	35%	20%	10%	5%
Jan	20.07	23.61	30.88	40.14	57.34	100	100	100
Feb	12.50	14.71	19.23	25.00	35.71	62.50	100	100
Mar	12.19	14.34	18.75	24.38	34.82	60.94	100	100
Apr	9.38	11.03	14.42	18.75	26.79	46.88	93.75	100
May	18.75	22.06	28.85	37.50	53.57	93.75	100	100
Jun	51.56	60.66	79.32	100	100	100	100	100
Jul	75.00	88.24	100	100	100	100	100	100
Aug	93.75	100	100	100	100	100	100	100
Sep	53.16	62.54	81.78	100	100	100	100	100
Oct	59.38	69.85	91.35	100	100	100	100	100
Nov	31.25	36.77	48.08	62.50	89.29	100	100	100
Dec	29.85	35.11	45.92	59.69	85.27	100	100	100

To maintain wetland ecological function, a major hydrologic criterion is to maintain its historical flood inundation frequency.

6. **Sediment supplies must be comparable to natural, historical watershed sediment yields to maintain the dynamics of river morphology such as riffle-pool sequence, rippl/dune/antidune bed forms as well as erosion and deposition cycles including seasonal fluctuations of turbidity or sediment load. It is important that the natural river flow and sediment regimes especially flooding dynamics are also maintained to ensure dynamic equilibrium of the river geomorphology.** ***[Watershed sediments contain rich nutrients and organic materials for benthic communities needed by fish and fauna and fine sediments also act as cleaning agents for gravel beds where fish spawn.]***

Channel Patterns vs. Sediment Load

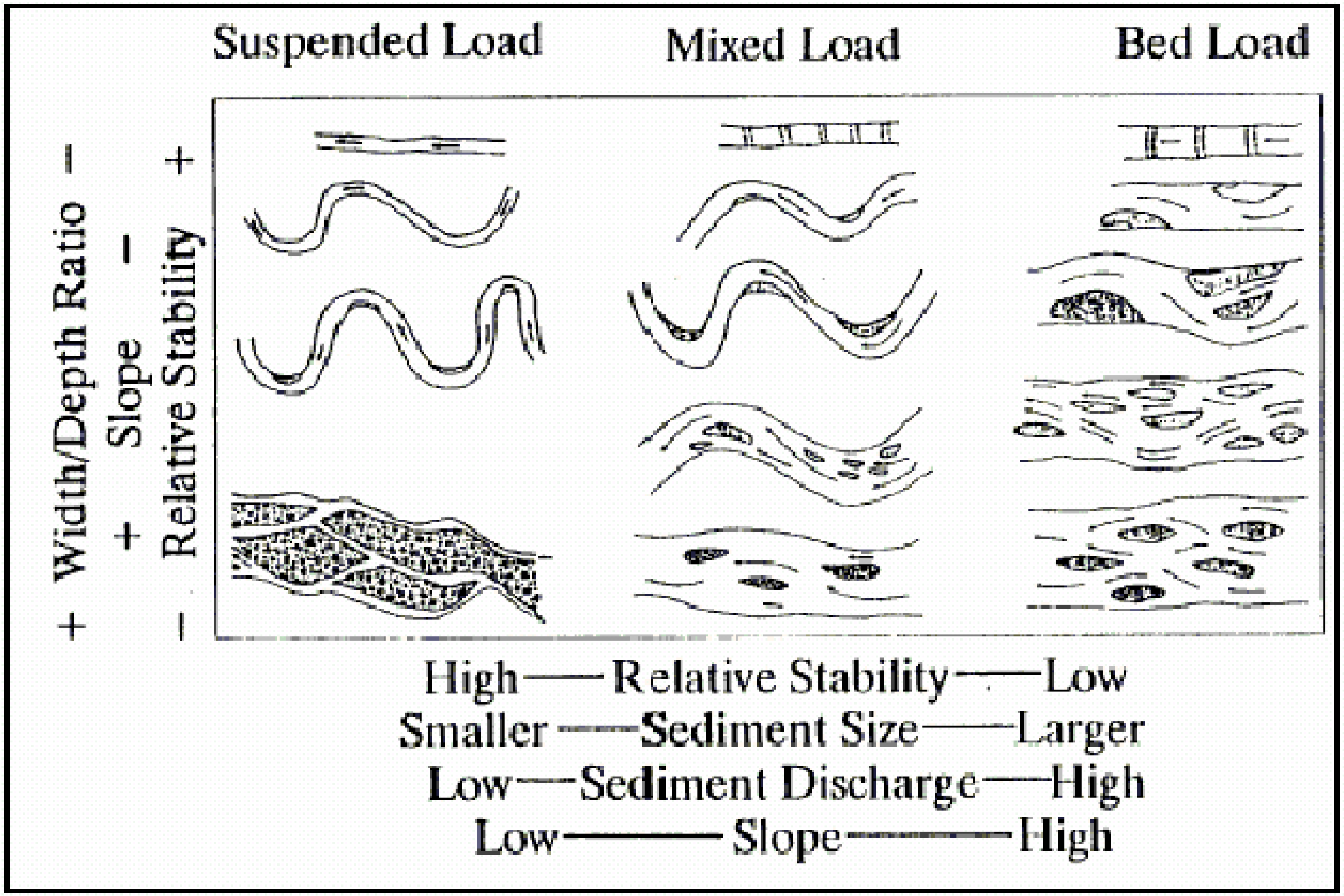


Figure 3.12 Channel Classification Based on Pattern and Type of Sediment Load (after Schumm, 1981)

On Adaptive Planning and Management of River Basins

- **Master plans are prepared by the government so that this is viewed by the community as an end project and that the implementation of the masterplan is the sole responsibility of the government.**
- **Since water resource systems are evolutionary in nature due to land use change, anthropogenic activities, economic change and climate change, then master plans should be adaptive and continuously updated so that master plans should be viewed as a guide to watershed management actions and that plans can be revised and modified through actual, local experiences.**

- **In this sense, watershed plans must be adaptive or work in progress so that the planning process is iterative and interactive.**
- **An important component of adaptive planning must ensure active stakeholder participation and stakeholders should be engaged in problem identification, knowledge generation and project implementation supported by science-based, and monitoring and assessment studies.**
- **In essence, this is community-based planning (bottom-up planning policy) rather than planning handed down from the national government (top-down planning).**

Conclusions

- **In planning and managing the Agusan River basin, objective measures should be established and followed to ensure that ecological goals are met.**
- **Understanding the interactions of hydrology, geomorphology and ecology and the temporal and spatial scales of fluctuations of these processes is needed in developing the river basin management objectives.**
- **It is recommended here that adaptive planning and management should be the approach used in Agusan River basin for sustainable fisheries that includes iterative planning, knowledge generation and project implementation with all stakeholders supported by science-based monitoring and assessment studies.**

Last Slide!