The Sesan and Sre Pok River Basins

BRIDGE: Building River Dialogue and Governance

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The Sesan and Sre Pok River Basins

Research and text by Daniel Constable

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BRIDGE
Building River Dialogue and Governance (BRIDGE) is an initiative that focuses on enhancing water governance capacities in 14 trans-boundary rivers and lakes in five regions across the globe. BRIDGE is implemented by IUCN with the support of the Swiss Agency for Development and Cooperation (SDC). In the Mekong region, BRIDGE activities are carried out in the Sekong, Sesan and Sre Pok River Basins (collectively called the 3S Basins).

The project seeks to facilitate cooperative processes in the 3S region by developing and strengthening water governance capacities through governance reforms, stakeholder dialogues and knowledge exchange programmes to catalyse trans-boundary cooperation for equitable and sustainable water resources development.

For more information visit: www.iucn.org/bridge and www.3sbasin.org.trans-boundary

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Preface

Over the past half century the Mekong River has been extensively studied for its potential to support development in and serve as a connecting thread between the nations of Southeast Asia. As early as the 1950s the Mekong River Basin was identified as a key asset in the development of the region. Within the Mekong, specific areas such as the Mekong Delta and the Sekong, Sesan, and Sre Pok Basins, known collectively as the "3S Basins," are especially important for both development and biodiversity conservation. The 3S Basins host the largest and most important trans-boundary tributaries of the Mekong. Together, these rivers provide 18% of the Mekong's annual total discharge and support communities throughout the region through the migration of fish, flow of water and sediments, provision of natural resources and fertile agricultural land, and important ecosystem services. However, the basins' topography and natural resources also make them valuable for development. In the last two decades significant forest areas here have been cleared to make way for agriculture and rubber plantations, and a number of hydropower dams have been constructed.

Recognising both the potential benefits and risks from the development of the 3S Basins, the Asian Development Bank (ADB) funded a project from 2008 to 2010 to analyse development and trans-boundary management in the basins.[1] The study found that smart development in the 3S Basins have a high potential for improving local livelihoods and quality of life, but that without agreement and coordinated development between stakeholders this opportunity could be lost. In particular, hydropower emerged as an area where trans-boundary planning had the potential to maximise benefits and minimise negative impacts. The project also focused on building capacity for trans-boundary communication and planning, leading to the development of a web portal to house and make available relevant information. As part of the BRIDGE project, this website has been revived and can be viewed at www.3sbasin.org.

One reason for writing this updated profile was the relative lack of easily accessible information for the Sesan and Sre Pok Basins as distinct areas, rather than as components of two separate management areas divided between Cambodia and Viet Nam.[2] Although heavily studied, data for the 3S Basins can nevertheless be difficult to access and is often disaggregated according to administrative sub-areas, rather a than hydrological basin boundaries. The profile takes advantage of reports published by the MRC, from National Mekong Committees for Cambodia and Viet Nam, and recent reports by consulting groups, NGOs, and scientific researchers. It is our hope that this document will help interested parties better understand the Sesan and Sre Pok and that this adds to the discussion on water governance in the 3S Basins as a whole. With shared understanding, enhanced governance and management of these critical basins can be better discussed based on common facts.

[1] ADB, 2010a.
[2] For information on the Sekong Basin, *see* Meynell, 2014.

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List of abbreviations

3S	Sekong, Sesan and Sre Pok (River Basins)
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BRIDGE	Building River Dialogue and Governance
CEPF	Critical Ecosystem Partnership Fund
CR	Critically Endangered
DONRE	Department of Natural Resources and Environment
EIAs	Environmental Impact Assessments
EN	Endangered
GDP	Gross Domestic Product
GMS	Greater Mekong Sub-region
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
LC	Least Concern
LMB	Lower Mekong Basin
MAFF	Ministry of Agriculture, Forestry and Fisheries
MARD	Ministry of Agriculture and Rural Development
MOE	Ministry of Environment
MONRE	Ministry of Natural Resources and Environment
MOWRAM	Ministry of Water Resources and Meteorology
MRC	Mekong River Commission
MRC- HYCOS	MRC- Hydrological Cycle Observation System
NGO	Non-government organisation
NMC	National Mekong Committee
NP	National Park
NR	Nature Reserve
NT	Near Threatened
NTFP	Non-timber forest product
PA	Protected area
PF	Protected Forest
PNPCA	Prior Notification, Prior Consultation, and Agreement
PPC	People's Party Committee
TEC	Threshold level effect concentration
UNWC	Convention on the Law of Non-Navigational Uses of International Watercourses (also called the UN Water Courses Convention)
VU	Vulnerable
WB	World Bank
WQI	Water Quality Index
WS	Wildlife Sanctuary
WWF	World Wide Fund for Nature

1. Overview

1.1. Location and description

The Sesan and Sre Pok are trans-boundary basins of the Mekong River, shared by Cambodia and Viet Nam. The 18,800 square kilometre (km^2) Sesan Basin lies between the adjacent Sekong Basin, to its north, and the Sre Pok Basin to its south. The 30,900 km^2 Sre Pok Basin is the largest of the three basins (see Figure 1). [3]

As it flows from Viet Nam to Cambodia the Sesan River stretches 460 kilometres (km) before joining the Mekong River. The border of the basin in Viet Nam runs along the spine of the Annamite Mountains, reaching to within 75 km of the town of Quang Ngai on the coast of Viet Nam. The Sre Pok River also originates high in the Annamite Mountains, and travels for approximately 450 km before joining the Mekong River. In Cambodia the Sre Pok traverses more gentle terrain until it meets with the Sesan River, from where the combined flows travel 38 km to meet the mainstream Mekong River above the town of Stung Treng. The Sesan Basin primarily overlaps with the provinces of Gia Lai and Kon Tum in Viet Nam and with Ratanakiri and Stung Treng in Cambodia. The Sre Pok Basin overlaps with the provinces of Dak Nong, Dak Lak, Lam Dong and Gia Lai in Viet Nam and with Ratanakiri, Mondulkiri, and Stung Treng in Cambodia.[4]

An overview of the location and relevant parameters for the Sesan and Sre Pok River Basins is shown in Table 1 (next page).

[3] Sekong is also transliterated as Xe Kong or Xekong. In this report the river, basin and town are referenced as Sekong, while dams use “Xe.” Sesan can also be written as Se San. This report follows previous ADB reports in using the first spelling.
[4] The basin also overlaps 49 km^2 of Kratie Province, but this small area is not considered as large enough to be relevant.

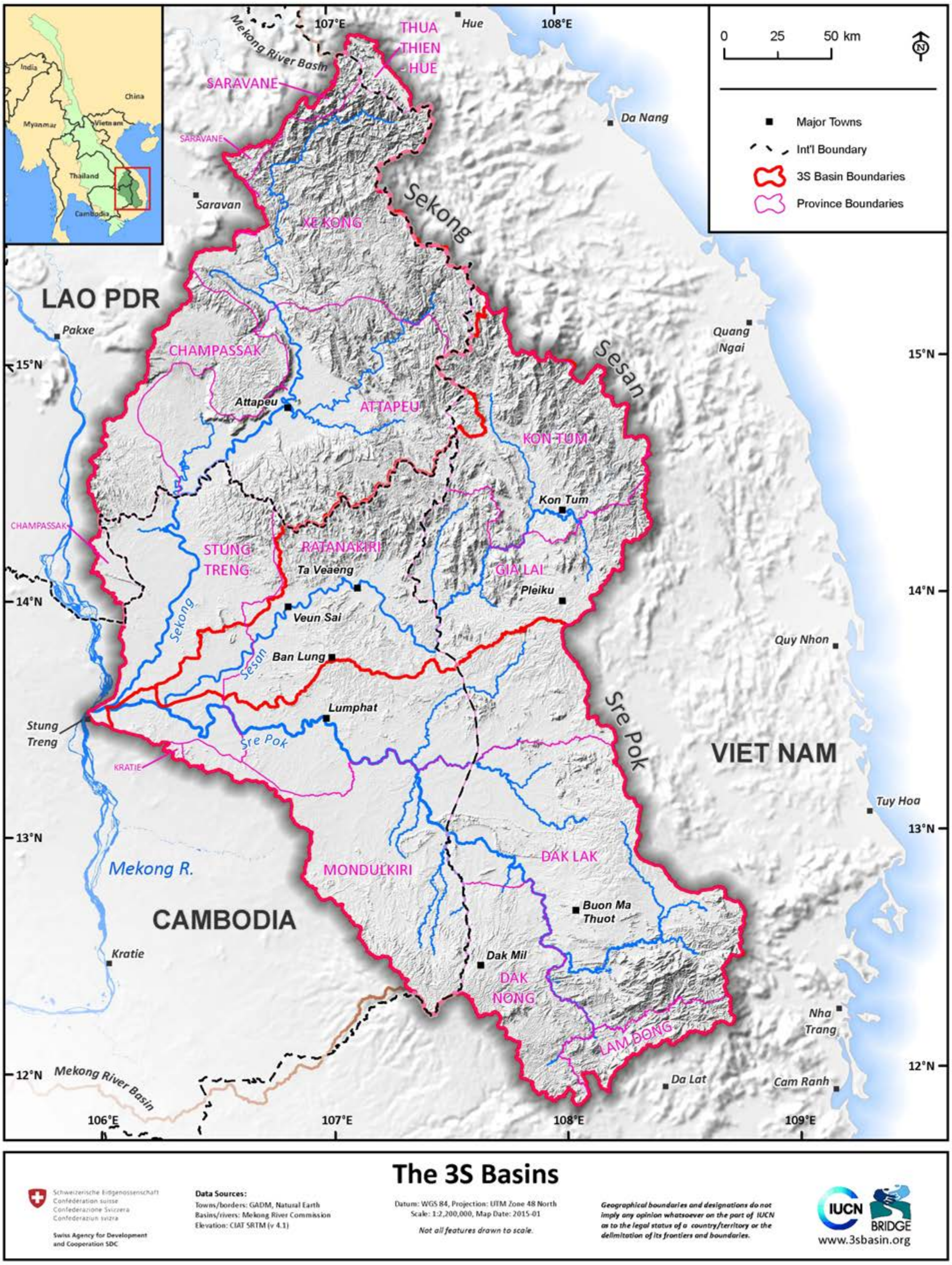
Table 1: Overview of the Sesan and Sre Pok River Basins[5]

Variable	Sesan		Sre Pok	
	Cambodia	Viet Nam	Cambodia	Viet Nam
Basin area (km^2)	7,566	11,255	12,780	18,162
Basin length (km)	130	140	180	150
Basin width (km)	90	120	160	220
River length (km)	225	237	265	160 (Sre Pok only)
Elevation range (m)	56–1,434	129–2,390	45–1,081	140–2,409
Average elevation (m)	273	778	218	525
Average slope (deg.)	6	10	2.4	6.8
Provinces	Ratanakiri, Stung Treng	Gia Lai, Kon Tum	Mondulkiri, Ratanakiri, Stung Treng, Kratie	Dak Lak, Dak Nong, Gia Lai, Lam Dong
Major towns	Ban Lung, Veun Sai	Kon Tum, Pleiku	Lumphat	Dak Mil (Dak Min), Buon Ma Thuot
Population (2012)	95,603	896,812	128,074	2,139,470
Pop. density (pers./km^2)	13	80	10	118
Average precipitation (mm)	1,965	2,115	1,569	1,575
Average temp. (°C)	22.6	19.3	23.2	21.2
Protected areas	Virachey NP	Chu Mom Ray NP, Bac Plei Ku NR, Kon Ka Kinh NP, Ngoc Linh (Kon Tum) NR	Lomphot NP, Nsok PF, Mondulkiri PF, Phnom Prich WS, Pnom Namlear WS	Bi Dup-Nui Ba NR, Chu Hoa NR, Chu Yang Sin NR, Dak Mang NR, Ho Lak, Nam Ca NR, Nam Nung NR, Ta Dung NR

Note on abbreviations: National Park (NP); Nature Reserve (NR); Protected Forest (PF); Wildlife Sanctuary (WS)

[5] Community forests are not listed here under protected areas. Source: multiple, see relevant report sections.

Figure 1: Map of the location of the Sesan and Sre Pok River Basins



1.2. Governance and legislative framework

Here, governance is a reference to the interaction of various actors, such as government, civil society, and other groups, in management, decision-making, and policy making, whether at local, national, or international levels.

Governance in the Sesan and Sre Pok is complicated by the trans-boundary nature of the basins. The rivers are subject to the laws of both Viet Nam and Cambodia as they pass through these territories. Although mechanisms exist to address some trans-boundary issues through dialogue (for example through the Mekong River Commission or MRC), national laws take precedence and Viet Nam and Cambodia have no comprehensive, enforceable treaties governing shared development and use of their shared waters. There have been long-running attempts to address this through the MRC's dialogue process. However, the Sesan and Sre Pok effectively remain managed under the legislation of Viet Nam in their upper reaches and in their lower reaches by Cambodian law.

The Sesan and Sre Pok Basins are also influenced by local institutions and interests. Local governments have been given significant leeway in implementing development projects and overseeing environmental protection. This affords local authorities some autonomy to raise funds and carry out development projects at the district and provincial level, and may increase in the future as both governments experiment with decentralisation. However, regulatory power and funding still rests with the respective central governments.

Cambodia

The Kingdom of Cambodia (referred to in this document as "Cambodia") is a constitutional monarchy. The 1993 constitution established a parliamentary, representative democracy where executive power is vested in the government, led by a prime minister, and legislative power rests with the Senate and the National Assembly.

Environmental protection falls under the auspices of the Ministry of Environment (MOE), which was also established in 1993. An exception is forest management, which is overseen by the Ministry of Agriculture, Forestry and Fisheries (MAFF). In practice, multiple ministries and government agencies have overlapping responsibilities which complicates development and conservation activities.[6] Most of the legislation underlying environmental regulation in Cambodia was also written into law in the 1990s, including the Law on Environment Protection and Natural Resource Resources Management (1996), which is the primary environmental law in Cambodia. Although this law requires Environmental Impact Assessments (EIAs), including for hydropower and irrigation projects, good examples of EIAs in application appears limited.[7]

The Land Law (2001) granted local communities and minority groups customary use rights to some areas and required compliance with environmental subjects outlined in other legislation. Additional laws in 2002 and 2006 helped allocate production forests to local communities under a community forestry management system. Water resources and hydropower are covered by legislation on related themes such as the laws mentioned above and in the energy development sector. Large water resources projects often fall under Cambodia's national development plans, for example the Strategic Plan on Water Resources Management and Development. Although there are clear, interrelated impacts between the multitude of development projects that fall under such plans, to date there has been relatively little coordination and discussion about their cumulative impact, either nationally or internationally.[8]

[6] World Bank. Cambodia Environment. <http://go.worldbank.org/ESXAE89OF0>. Accessed 21 July 2014.
[7] Grimsditch, 2012.
[8] ADB, 2010a.

Viet Nam

The Socialist Republic of Viet Nam (referred to in this document as "Viet Nam") has a one-party political system, led by the Communist Party of Viet Nam, and follows a 1992 constitution (amended in 2001). Under this system the government is led by a prime minister and a National Assembly is granted legislative power. The Ministry of Natural Resources and Environment (MONRE) is the most powerful government body that oversees environmental issues. Similar to Cambodia, there are significant overlaps with other ministries and agencies, including those that oversee development.[9] For example, water resources are overseen by both MONRE and the Ministry of Agriculture and Rural Development (MARD). The provincial level equivalent to MONRE – the Department of Natural Resources and Environment (DONRE) – also has power to make decisions related to the environment, and is accountable to provincial People's Party Committees (PPCs). Below DONRE, sub-DONRE district-level offices help implement decisions from above.

Viet Nam has a wide variety of laws and decisions which address and are related to development and environmental impacts. At the highest level are laws such as the Water Resources Law, Construction Law, Land Law, and the Law on Environmental Protection. The National Water Resources Council, which was established by the 1998 Water Resources Law, is chaired by the Deputy Prime Minister and attempts to better coordinate the actions of various institutions, in relation to water resources. Land and water resources in Viet Nam are defined as being owned by all citizens, but "entrusted" to the central government.

Viet Nam has identified several priority projects focusing on "integrated planning for sustainable development of water resources," climate change adaptation, flood forecasting, fisheries conservation, and watershed forest protection across the 3S Basins.[10] However, similar to Cambodia there are no plans that effectively integrate the development of industry, water resources, and socio-economic development. For example, industrial plants have been developed without full forethought for the impact on water quality in immediate downstream areas.[11] Although certainly not unique to Viet Nam, this lack of effective integration in legislation, governance, and development planning makes for a more complicated management situation.

Major environmental laws for Cambodia and Viet Nam are summarised in Table 2.

[9] Hong, et al., 2013.
[10] Viet Nam National Mekong Committee (VNMC), 2010, p. 100.
[11] VNMC, 2010, p. 127.

Table 2: Selected environmental laws and policies in Cambodia and Viet Nam

	Law	Notes	Year
Cambodia	National Strategic Development Plan (NSDP)	Addresses rebuilding and expanding irrigation infrastructure, especially in border areas such as in the 3S Basins	2014–2018
	National Fisheries Law	Provides basis for management of inland fisheries (but cannot influence extraterritorial issues affecting fisheries)	2006
	National Energy Development Plan	Plans to increase energy production and access, including from hydropower	2005–2024
	Rural Electrification by Renewable Energy	Policy for 100% electricity access in rural areas by 2020	2006
	National Water Supply and Sanitation Sector Policy	Outlines goal of providing improved water and sanitation facilities to 100% of population by 2025	2004
	National Water Resources Policy (NWRP)	Aims to protect water resources, resolve conflicts (in cooperation with relevant institutions), and support implementation of a national water policy	2004
	Law on Environment Protection and Natural Resources Management	Governs natural resource management and includes requirement for EIAs	1996
Viet Nam	Law on water resources	Focuses on Integrated Water Resources Management (IWRM) as the foundation for improving water quality and quantity. Law addresses some aspects of IWRM, RBO, and stakeholder participation. This version revised the original Water Law of 1998 (No. 8/1998/QH10)	2012 (1998)
	Land Law	Reaffirms state ownership of land, while allowing for use by people over long term periods; 2003 law updated in 2014	2014 (2003)
	Law on Environmental Protection	Established regulations on use of natural resources, institutional management agreements, and the requirement to conduct EIAs; 2014 update added to sections on green growth and other subjects.	2014 (1993)

In addition to national laws, both countries have also signed several treaties and conventions related to the environment, natural resources, and trans-boundary cooperation. The most recent, and one of the most promising for trans-boundary water governance, is the UN Convention on the Law of Non-Navigational Uses of International Watercourses (also called the UN Water Courses Convention or UNWC), which came into force in August 2014, after Viet Nam became the 35th signatory.[12] However, the Convention does not have legal standing in the 3S Basins until another Mekong Basin country becomes a signatory.

[12] Formally titled the "U.N. Convention on the Law of Non-Navigational Uses of International Watercourses."

Table 3: Environmental conventions to which Cambodia and/or Viet Nam are Party[13]

Convention	Country / signatory date	
	Cambodia	*Viet Nam*
Convention on Biological Diversity (CBD)	1995	1993
Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)	1997	1994
International Tropical Timber Agreement (ITTA)	1994	2014
Convention on Wetlands of International Importance (Ramsar Convention)	1999	1989
UN Framework Convention on Climate Change (UNFCCC)	1995*	1992
World Heritage Convention (WHC)	1991	1987
UN Watercourses Convention (UNWC)	N/A	2014

Box 1: The United Nations Watercourses Convention

In 2014 Viet Nam became the 35th country to sign the UN Watercourses Convention, bringing it into force. The UNWC outlines several key areas to improve cooperative use of international waterways while respecting existing treaties such as the 1995 Mekong Agreement (see section entitled "Mechanisms for intergovernmental cooperation"). Although no other country in Asia has yet signed the UNWC, the provisions contained therein could do much to improve trans-boundary management in the Mekong Basin. As downstream countries, Viet Nam and Cambodia are alert to the actions related to upstream development in Lao PDR and China. Both countries may also be impacted by actions taken in the other. For example, dams in Viet Nam could impact downstream Cambodia while development in Cambodia could impact fish migration as well as water and sediment flows (which in turn influence salinity and crop and fisheries production) in the Mekong Delta. By following the provisions outlined in both the UNWC and previous international water laws, such as the principles to do no harm, equitable and reasonable use of water resources, prior consultation, and joint development and planning, Viet Nam, and future signatories, can showcase trans-boundary cooperation in the 3S, the Mekong, and greater Asia.

Mechanisms for intergovernmental cooperation

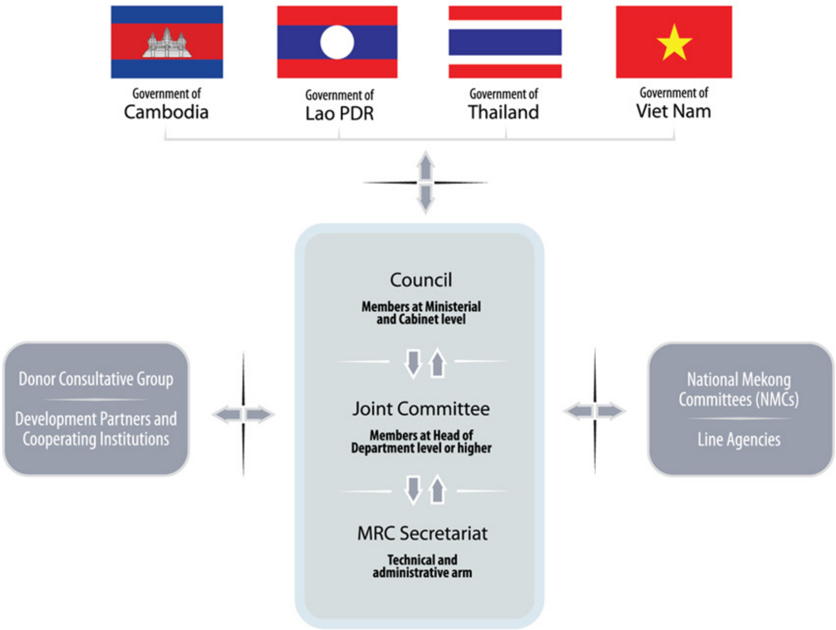
The MRC is currently the main official mechanism for intergovernmental cooperation surrounding water resources in the Lower Mekong Basin or LMB (roughly, the area of the Mekong Basin not in China). Established in 1957 as the Mekong Committee, the name and responsibilities changed in 1995, when the "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin" (also known as the "Mekong Agreement") was signed. The Mekong Agreement requires riparian countries to inform the MRC regarding activities on the mainstream Mekong and tributaries that could affect other riparian countries. This requirement is known as Prior Notification, Prior Consultation, and Agreement (PNPCA) and is intended to coordinate notification and development within the Mekong Basin. However, only the *notification* component of PNPCA applies to tributaries such as the Sesan and Sre Pok. Furthermore, as specified by the Agreement, the MRC has no regulatory or enforcement authority. Rather, it serves as a dialogue platform for airing concerns, and as an advisory body for improved management of the LMB. In this role it can help coordinate water resources, development, and other projects that could potentially impact the basin. This advisory role is carried out under eleven separate but interrelated

[13] *Signed Kyoto Protocol. Source: <https://treaties.un.org>

programmes on areas such as agriculture and irrigation and sustainable hydropower (see Table 4). The MRC also serves as a body to help re-disperse development aid provided by international development agencies and development banks.

The MRC consists of staff from the four riparian countries (Cambodia, Lao PDR, Thailand, and Viet Nam), as well as international experts. China and Myanmar have been granted status as official dialogue partners, which allow them to offer comments on development in the basin. The MRC has secretariat offices in Vientiane, Lao PDR and Phnom Penh, Cambodia.[14] In addition, organisations such as the Asian Development Bank (ADB) and IUCN (International Union for Conservation of Nature), among others, are official observers and can attend formal MRC meetings.

Figure 2: Structure of the Mekong River Commission[15]



Since its inception the MRC has focused on intergovernmental, trans-boundary cooperation for development. However, although the MRC has been successful in some areas, such as promoting navigation safety and data management, it has faced criticism for its inability to greatly improve trans-boundary cooperation and governance, especially in the water resources and hydropower sectors, where countries have proceeded along their own development pathways.

[14] Agreement on the cooperation for the sustainable development of the Mekong River Basin. *Signed at Chiang Rai on 5 April* 1995.
[15] MRC. 'About the MRC'. <http://www.mrcmekong.org/about-mrc/>. Accessed 10 July 2014.

Table 4: MRC programme areas[16]

Programme	Focus area(s)
Agriculture and Irrigation	Improve irrigation and water use, land cover and land use change monitoring
Basin Development Plan	Support coordinated, sustainable, and equitable development
Climate Change and Adaptation Initiative	Climate change adaptation planning
Environment	Projects focused on long-term sustainability of economic development
Fisheries	Promote trans-boundary cooperation to protect and use fisheries to address socio-economic development goals
Flood Management and Mitigation	Provide technical advice and coordination, emergency management
Information and Knowledge Management	Make relevant information and tools available to stakeholders
Initiative on Sustainable Hydropower	Improve cooperation in construction and management of hydropower projects throughout the region
Integrated Capacity Building Programme	Provide capacity-building training to staff of MRC and National Mekong Committees
Integrated Water Resources Management	Improve integrated management across the basin
Navigation	Improve safety and increase trade opportunities

In addition to intergovernmental organisations such as the MRC, several national and local groups also work on issues related to water resources in the Sesan and Sre Pok. In Cambodia these include farmer user groups, fisheries communities, water and sanitation user groups, and others working on forestry and community ecotourism.[17] Similar groups, such as the Farmer's Union, exist in Viet Nam. Finally, several non-governmental organisations work in the area, including International Rivers and the 3S Rivers Protection Network.[18] These groups have varying goals and responsibilities, but often work to increase local people's income and manage natural resources through advocacy, education, and cooperation at the local level.

Access to and availability of information

Access to information is an impediment to cooperation and improved management of the Sesan and Sre Pok Basins.[19] At the national level both Cambodia and Viet Nam state support for information sharing. However, data access is limited for some forms of information, such as future development plans.[20] Lack of data access can hinder trust between stakeholders and can lead to a misunderstanding of some of the most important issues, such as making connections between enhanced integrated planning and improved water quality and availability. Without easy access to accurate and understandable data, decision makers do not have the information they need to make appropriate and justifiable decisions.

To help increase access to information the MRC makes numerous reports available on their data portal and helps compile data from riparian countries.[21] However, some important datasets are restricted access, due to requirements imposed by the riparian state members. The MRC also aggregates many data sources based on defined MRC sub-areas (sections of a hydrological basin, often cut at a national boundary). For the 3S Basins the MRC has divided the area into three sub-areas (SAs): SA-7L, covering Lao PDR's portion of the Sekong, SA-7C, which includes Cambodia's territory in all three basins, and SA-7V, which

[16] MRC. 'About the MRC'. <http://www.mrcmekong.org/about-mrc/>. Accessed 10 July 2014.
[17] CNMC, 2011, p. 114.
[18] 3SPN. '3S Rivers Protection Network'. <http://www.3spn.org/>. Accessed 4 September 2014.
[19] ADB, 2010a, p. 8.
[20] Ibid., p. 36.
[21] Mekong River Commission Data and Information Services. <http://portal.mrcmekong.org/>. Accessed 2 May 2014.

represents Viet Nam's overlap with the Sekong, Sesan, and Sre Pok Basins.[22] These sub-areas are a logical compromise given the sovereign nature of each country, but make it difficult to compile data for trans-boundary basins. As such, there is no easy way to query data for only the Sesan or the Sre Pok.

Hydrometerological data is of special interest for water management. Historical data is somewhat limited, and inconsistent for much of the 3S Basins, but data has been acquired regularly since 2008. In the Sesan, historical data is available from four sites, two in Viet Nam and two in Cambodia. These sites have intermittent records for water level and discharge since the mid-1960s, plus standard hydrological parameters like precipitation. Due to gaps in discharge data only two of the three measurement stations (Andaung Meas and Veun Sai) in Cambodia's portion of the Sesan can be used as a reliable, historic baseline.[23] Hydrological measurement stations in Viet Nam also have limited data. For example, the two dedicated stations in the Sesan Basin, at Trung Nghia and Kon Tum have records from 1991–1997 and 1978–2005, respectively.[24] The lack of longer term data for even these few sites means that it is difficult to establish historical baselines or make predictions for the future, if using data from only within the 3S Basins.

[22] Viet Nam overlaps with two areas within the Sekong Basin. Acknowledging the hydrological reality, these areas are grouped into SA-7L.
[23] CNMC, 2011, p. 21
[24] VNMC, 2010, p. 26.

Figure 3: Map of hydrological monitoring stations in the 3S Basins

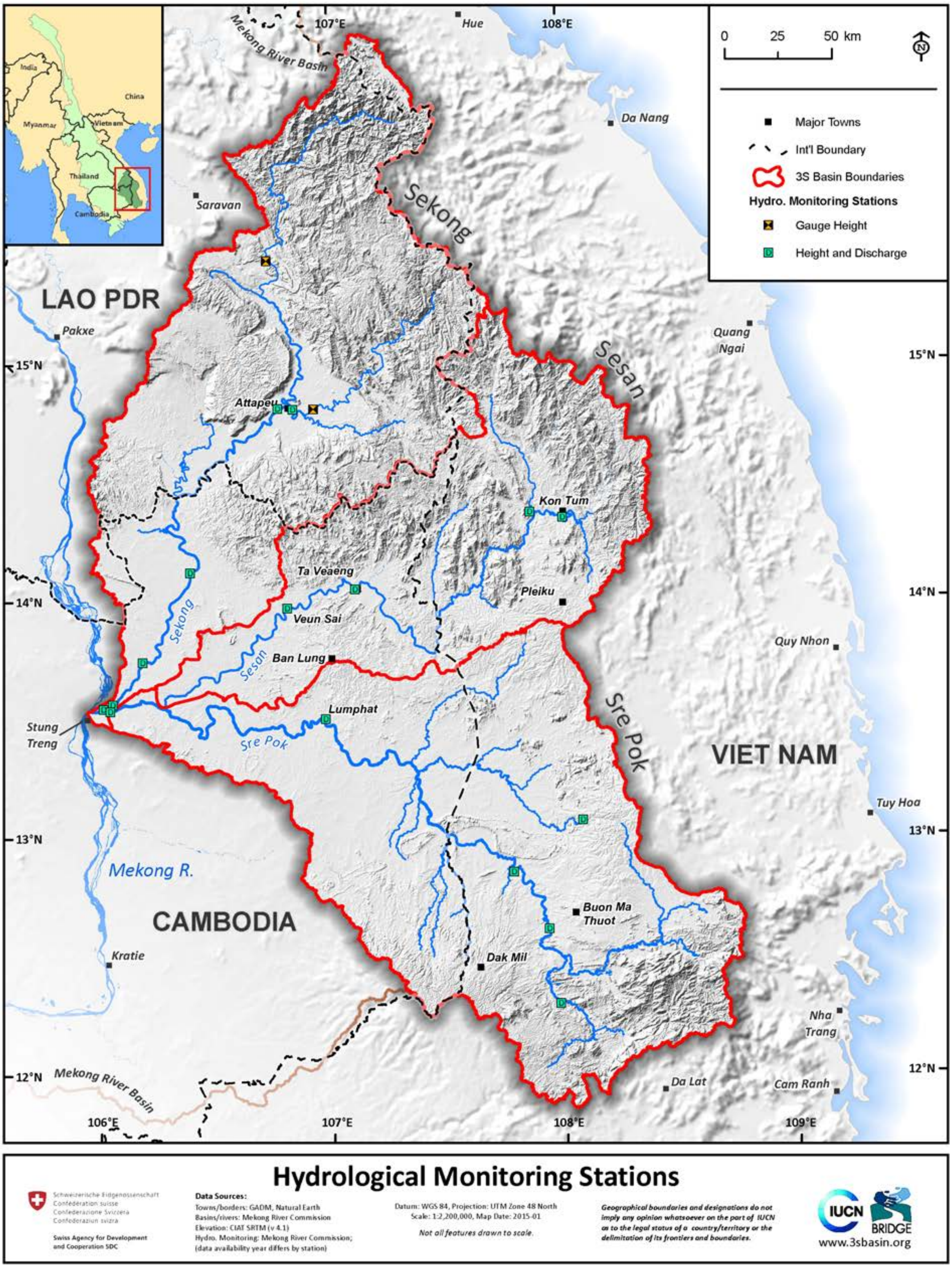


Table 5: Hydrological measurement stations in the Sesan Basin[25]

Station name	River	Country	Water level dates	Discharge dates
Voeun Sai	Sesan	Cambodia	1965-9, 2000-05 2008-present	1965-69, 2008-present
Andaung Meas	Sesan	Cambodia	2000-05, 2008-present	1965, 2008-present
Kon Tum	Dak Bla	Viet Nam	1966-69,1973,1984-06, 2008-present	1967-71,1974, 1984-present, 2006, 2008-present
Trung Nghia	Krong Poko	Viet Nam	1992-98, 2008-present	1992, 1993, 1995-98, 2008-present

There are more regular hydrometeorological stations in the Sre Pok than in the Sesan. The MRC maintains stations at Lumphat, Ban Don, Duc Xuyen, and Giang Son. In addition, the Viet Nam maintains a wide network of rain gauges and streamflow gauges within the basin. The longest running rain gauges are at Buon Ma Thuot (established in 1928), M'Drak (1942), and Dak Mil (1944). However, these frequently did not operate during periods of conflict; the actual useable period of record is much shorter.[26] Estimates for water demand are similarly lacking or when known are not necessarily shared.[27] Without accurate estimates of water use it is difficult to estimate trends or to quantify the magnitude of water surpluses or gaps.

Table 6: Reliable meteorological stations in the upper Sre Pok Basin (Dak Lak Province, Viet Nam)[28]

Station name	Latitude (N)	Long. (E)	Elevation	Period
Buon Ho	12.9166	108.2666	700	1977–2006
Buon Ma Thuot	12.6833	108.0833	490	1958–2006
Dak Nong	12.00xx	107.6833	660	1976–2006
M'Drak	12.6833	108.7833	478	1977–2006

Water quality is measured in select locations on a monthly basis, at best. A lack of water quality measurement stations on upstream tributaries of the two basins makes it difficult to identify intraseasonal changes in water quality or identify specific sources of pollution.

[25] MRC, 2009.
[26] VNMC, 2010, p. 24.
[27] Water demand is better studied in Viet Nam. For estimates within Viet Nam's portion of the 3S Basins (SA-7V), see VNMC, 2010.
[28] VNMC, 2010

Table 7: Water quality monitoring locations in the Sesan and Sre Pok Basins[29]

Station code	Station name	Basin/River	Country	Parameters
H014501	Stung Treng	Sesan	Cambodia	Electrical Conductivity Dissolved Oxygen Temperature Total Suspended Solids Calcium Magnesium Sodium Potassium Alkalinity Chloride Sulfate Total Nitrogen Total Phosphorous Nitrate Ammonia Chemical Oxygen Demand Faecal Coliform
H440102	Phum Pi	Sesan	Cambodia	
H440103	Andaung Meas	Sesan	Cambodia	
H450101	Lumphat	Sre Pok	Cambodia	
H451303	Ban Don	Sre Pok	Viet Nam	
H450701	Pleiku	Sre Pok	Viet Nam	

2. Geophysical profile

2.1. Topography

Both the Sesan and Sre Pok are characterised by large elevation ranges and high slopes. The Sesan stretches from 56 to 2,390 metres (m) above sea level (MASL) and is approximately 250 km long and 120 km wide between its furthest points.[30] The Sre Pok is larger, flatter, and has a lower average elevation than the Sesan. The basin ranges from around 50 to 2,409 MASL, nearly the same as the Sesan. However, this masks the fact that the majority of the Sre Pok is lower elevation, with only small areas in the southeast rising above 500 m. The Sre Pok Basin is approximately 330 km long and 225 km wide. In both basins elevation increases moving from west to east, where the Annamite Mountains lie (see Figure 3).

In Cambodia the Sesan Basin is generally flat with some rolling hills moving away from the river. Moving to the northeast, hilly terrain reaches above 250 m north of the Sesan River, above the town of Ta Veang, the mountains reach above 1,000 m and divide the Sesan from the Sekong Basin to the north.[31] In Viet Nam the terrain is more mountainous. The average elevation and slope here is 778 m and 10 degrees, respectively.[32] A broad valley runs from the town of Pleiku, to the north towards Kon Tum. In the uppermost reaches the terrain consists almost entirely of mountains, which hydrologically divide the westward flowing Sesan from rivers to the east, which discharge into the East Sea.[33]

[29] In the Sesan, measurements are taken at Phum Phi (on the Viet Nam-Cambodia border) and at Stung Treng. Source: MRC 2009.
[30] Unless otherwise noted, physical parameter values stated in this report, like elevation and slope, are calculated based on spatial data. For elevation, figures come from a digital elevation model available from CGIAR (http://srtm.csi.cgiar.org/).
[31] CNMC, 2011, p. 65.
[32] The average slope is biased by extremely steep slopes in the uppermost reaches of the Sesan Basin in Viet Nam. In most inhabited areas the slope is significantly lower.
[33] Someth, et al., 2013.

Figure 4: Elevation in the 3S Basins

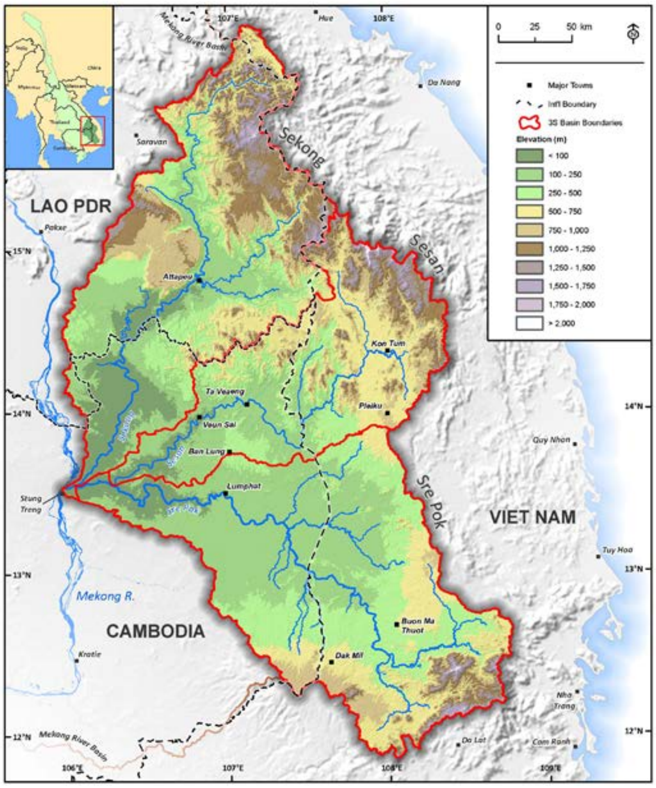
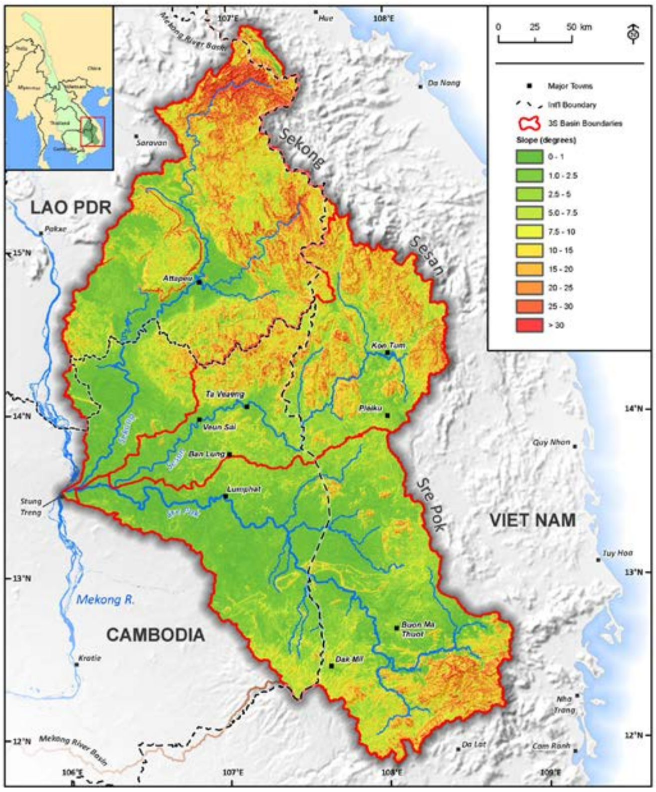
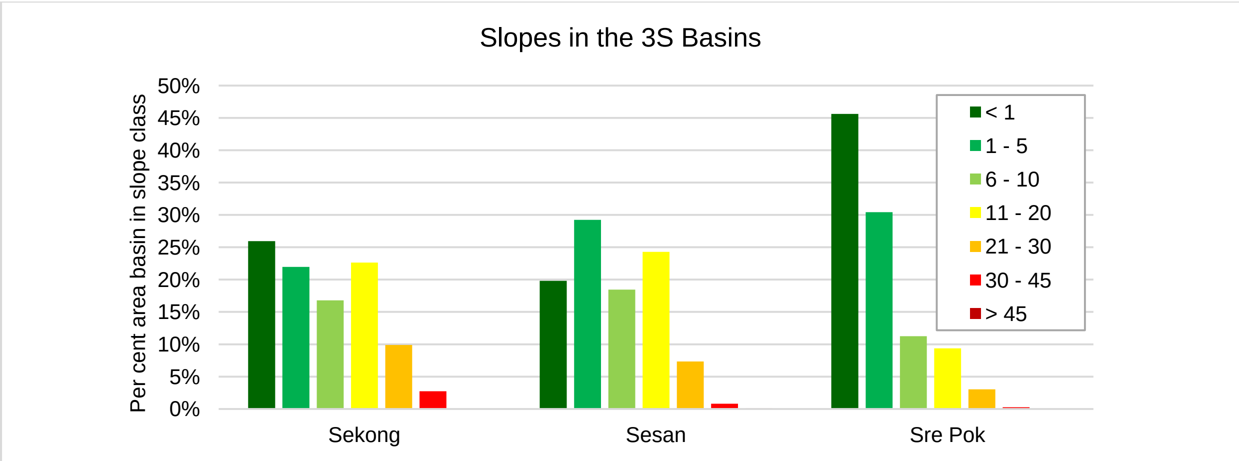


Figure 5: Slopes in the 3S Basins



The Sre Pok Basin is generally flat in its lower areas with small mountains north of Lumphat stretching east to the border with Viet Nam. There are some mountains in the southern area of the Sre Pok, west of Dak Mil. Just as with the Sesan, the Sre Pok's terrain is more mountainous in its upper areas, especially to the southeast of Buon Ma Thuot. However, the majority of Viet Nam's area in the watershed is also relatively low elevation (averaging 525 m). Around half of the Sre Pok Basin has a slope of less than 1 degree, although extremely steep slopes can be found in the upper basin. The Sre Pok is notably flatter than the Sesan, although it still has areas of high elevation and steep slopes.

Figure 6: Chart of slopes in the 3S Basins[34]



2.2. Geology

Geology, along with climate, is one of the few independent variables that influence the characteristics and behaviour of river basins.[35] The geology of the Sesan and Sre Pok includes a portion of the Kontum Massif. This area is one of the largest limestone massifs in the world and arguably the most important geological feature of the basins. High occurrences of limestone (karst) geology are associated with cave systems, nutrient-poor ecosystems, and often have relatively high numbers of associated endemic species, making this area of high biological interest.[36] In the upper areas of the basins much of the massif consists of metamorphic rock, including amphibolite, gneiss, and marble. In the lower basin the surface geology is dominated by alluvial deposits, with areas of sandstone, conglomerates, and siltstone.[37] Additional geologic features include a complex of basalt and sedimentary materials, which in some areas are known to bear valuable minerals and ores, including gold, aluminium, zirconia, and coal.

[34] Around half of the area of the Sesan Basin has a slope of less than five degrees, although extremely steep slopes can be found in the upper basin. Source: SRTM.
[35] Twidale, 2004.
[36] Nagy, et al., 2001.
[37] CNMC, 2011, p. 66.

2.3. Soils

Major soil types found in both basins include acrisols and ferrasols. Both soil types have relatively lower value for agricultural cultivation, but nonetheless are capable of supporting many crop types.[38] In the Sesan acrisols and ferrasols cover 80% and 13.7% of the basin, respectively. The Sre Pok Basin has a similar soil composition to the Sesan, but with relatively less acrisols (60%) and more ferrasols (20%). Alluvial and fluvisol soils are also of interest, due to their association with floodplains and high productivity areas. Their presence can help identify potential wetlands. Gleysols are associated with the riparian corridors along the lower Sre Pok. This soil type can be used for rice cultivation, but in the 3S Basins there is relatively little rice cultivated on these soils.

[38] Someth, et al., 2013.

Figure 7: Soil types in the 3S Basins

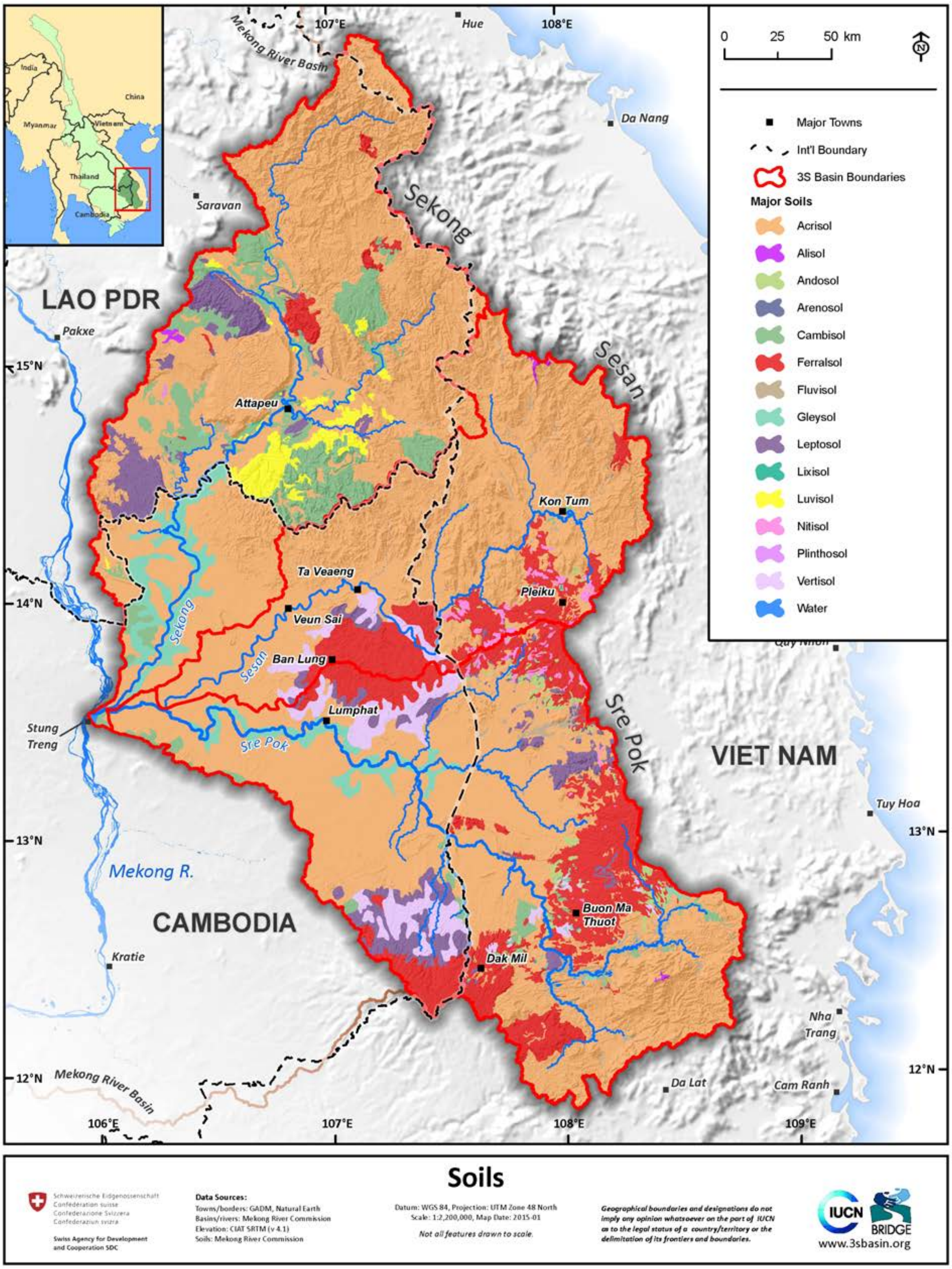


Table 8: Characteristics of selected major soil types[39]

Soil Type	Characteristics
Acrisols	Relatively unproductive soil for agriculture, acidic and lacks key nutrients. Crops that can tolerate this soil type include cashew and pineapple. Acrisols are susceptible to erosion.
Ferrasols	Lack key nutrients, but rubber trees can be grown on this soil type.
Gleysols	Waterlogged soil often found in areas with shallow groundwater, they can be used to cultivate rice or for animal pasture.
Leptosols	Rocky soil with limited potential for agriculture, including tree crops.
Vertisols	Productive agricultural soil with poor drainage, often used for crops such as peanuts or other crops tolerant of waterlogged soils.

Table 9: Proportion of soil types in the Sesan and Sre Pok Basins[40]

Soil type	Sesan		Sre Pok	
	Area (km^2)	*Per cent of basin*	*Area (km^2)*	*Per cent of total*
Acrisol	15,117	80.04%	18,699	60.43%
Alisol	37	0.20%	11	0.04%
Andosol	44	0.23%	438	1.42%
Arenosol	-	0.00%	-	0.00%
Cambisol	44	0.23%	612	1.98%
Ferrasol	2,594	13.73%	6,113	19.76%
Fluvisol	81	0.43%	576	1.86%
Gleysol	-	0.00%	937	3.03%
Leptosol	176	0.93%	1,730	5.59%
Lixisol	-	0.00%	-	0.00%
Luvisol	-	0.00%	-	0.00%
Nitisol	274	1.45%	180	0.58%
Plinthosol	-	0.00%	-	0.00%
Vertisol	519	2.75%	1,618	5.23%
Water	2	0.01%	26	0.08%
Grand Total	**18,888**	**100.00%**	**30,940**	**99.99%**

[39] Modified from Someth, et al., 2013.
[40] The Sesan has similar soil type distribution to the 3S Basins as a whole, but with a higher incidence of acrisols. Water is included as a cover type in the MRC database and includes reservoirs, such as above Yali Falls. Source: MRC database (2009).

2.4. Climate

Higher precipitation is correlated with increasing elevation within the Sesan and Sre Pok, and is highly seasonal, being influenced by the Southwest Monsoon.[41] As a result of the monsoon the majority of precipitation falls during the wet season between May and September, although in areas in the Annamite Mountains this is shifted to August to December.[42] An example of this seasonality is clearly shown in Figure 6 for an illustrative site in the lower Sesan.

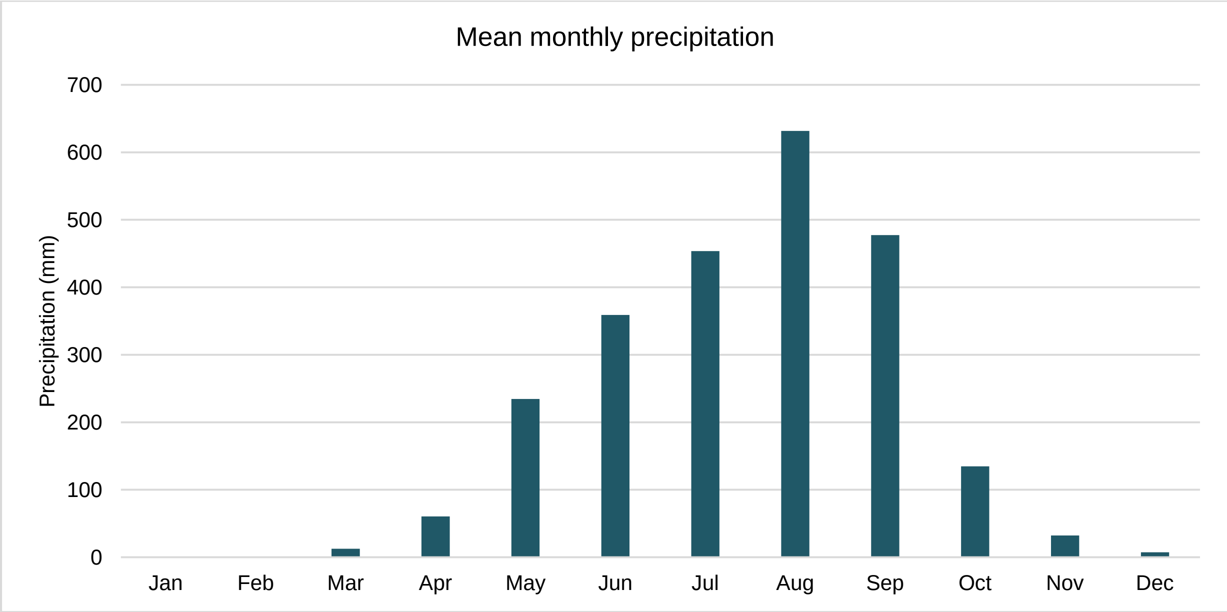
There are three hydrometeorological monitoring stations in the Sesan Basin and six long-term meteorological monitoring stations in the Sre Pok included in the MRC meteorological database.[43] However, few have accurate, long term data and stations in both basins have significant temporal gaps. As such, there is a data gap for many of the microclimates in the middle and upper parts of the basins. Furthermore, averages mask over large variations from month to month and at different elevations. Instead, climatic variables are included here as descriptors which help add to the background information on the area.

Precipitation

The Sesan Basin has a mean annual precipitation of 2,037 mm. In the lower portions of the Sesan 1,300–1,900 mm of precipitation falls, increasing to nearly 2,500 mm in its highest reaches.[44] The Sre Pok Basin is drier than the Sesan. In the lower portions of the Sre Pok an average of 1,569 mm of precipitation falls, increasing only slightly to 1,575 mm in its middle and upper areas, but up to nearly 2,800 mm in its highest reaches southeast of Buon Ma Thuot.[45] Precipitation records for the Sre Pok are much more complete than other hydrometeorological measurements. Since 1985 there has been a continuous record, although only select sites are available via the MRC- Hydrological Cycle Observation System (HYCOS) database for dates before the year 2000. Data for other sites must be accessed and compiled via other MRC databases.[46]

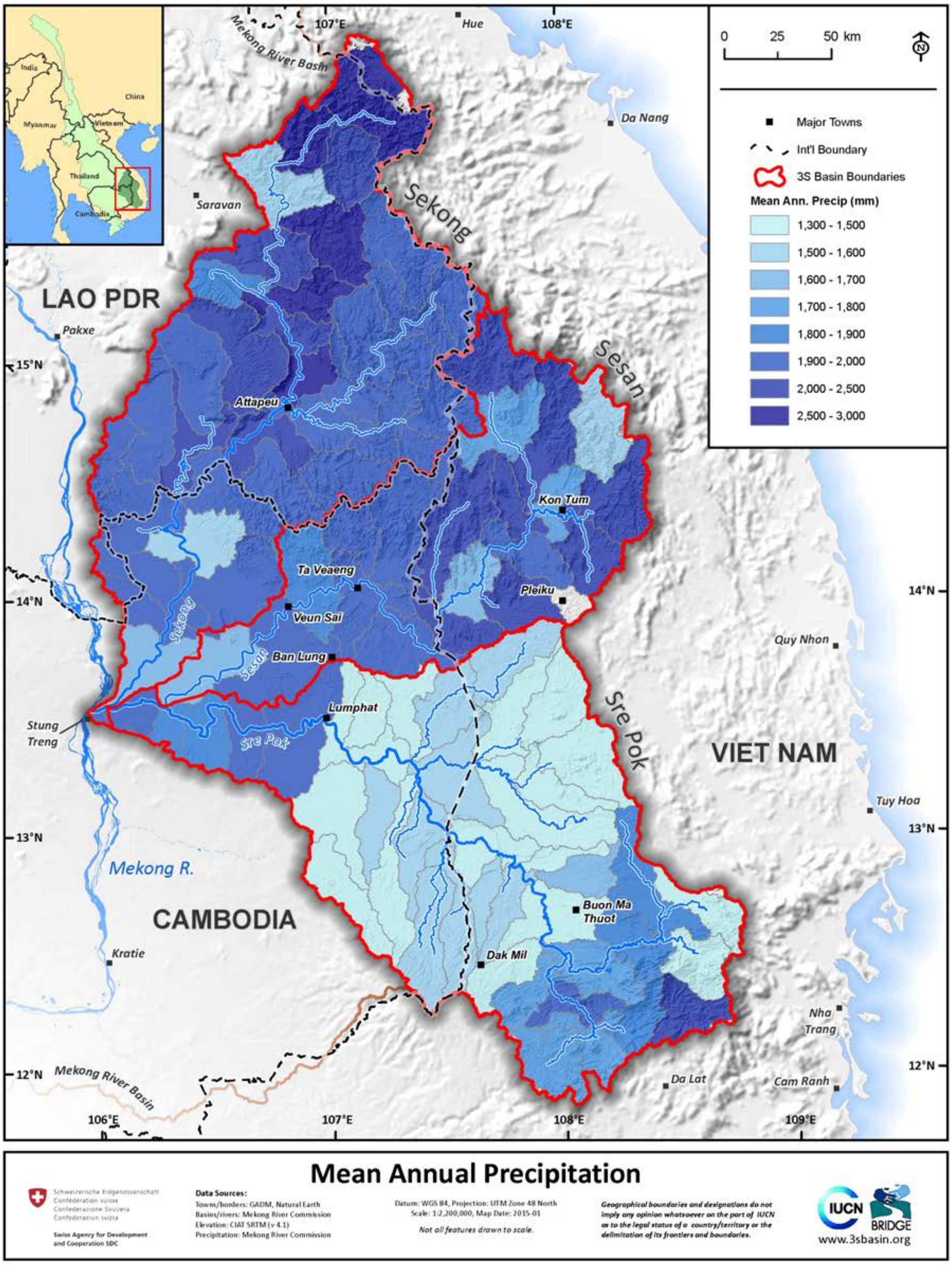
[41] CNMC, 2011, p. 11.
[42] VNMC, 2010, p. 28.
[43] VNMC, 2010, p. 24.
[44] Data provided by MRC, based on rain gauge measurements. An analysis of long term interpolated data from WorldClim (Hijmans, et al., 2005) predicts much higher precipitation in the highest reaches of the watershed. Using this interpolated data gives an annual, basin-wide mean of 2,383 mm of precipitation per year.
[45] Hijmans, et al., 2005.
[46] CNMC, 2011, p. 27.

Figure 8: Mean monthly precipitation in the lower Sesan Basin[47]



[47] Measurements are taken from the years 1961–1968 and 2000–2005. Source: Cambodia National Mekong Committee (CNMC) 2009; modified from Someth, et al., 2013.

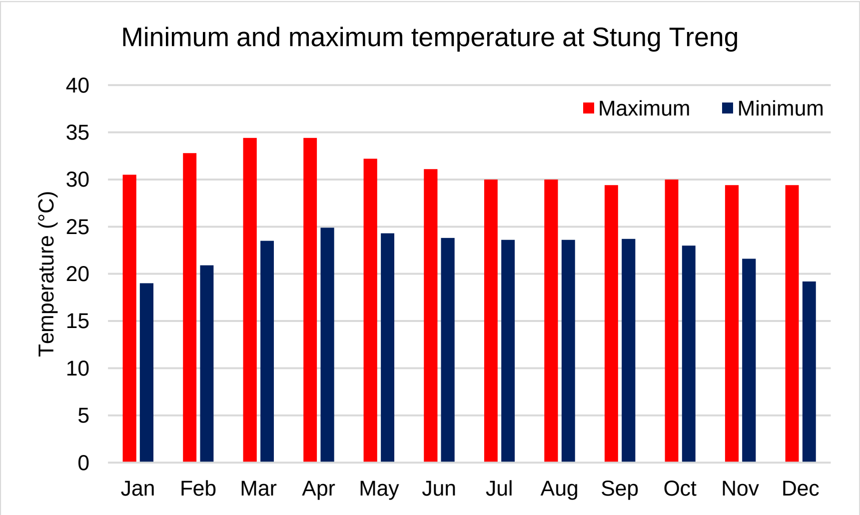
Figure 9: Map of mean annual precipitation in the 3S Basins



Temperature

Average temperature decreases with elevation as well as varies with the season. Basin-wide annual temperature in the Sesan averages 20.6°C. Areas below 1,000 m average 24°C, and can rise to 40°C immediately preceding the start of the wet season. At the Kon Tum meteorological monitoring station in the Sre Pok Basin the mean annual temperature is 23.5°C, but the mean maximum temperature can rise to above 35°C in March and April.[48] In the Annamite Mountains temperature models estimate that the mean temperature ranges between 15 and 20°C, but drops to nearly 10°C at the highest peaks.[49] In between these extremes temperatures fluctuate across the elevation range and vary with combinations of aspect (slope direction), land cover, and other factors. Cambodia has higher average temperatures due to its lower elevation. Average daily temperatures reach 36°C during April and May. Minimum temperatures during these times often fall 8–10°C below the maximum.[50] Temperatures at Stung Treng are similarly high and fluctuate only modestly throughout the year.

Figure 10: Minimum and maximum temperature at Stung Treng[51]



2.5. Hydrology

Hydrological features

Although rivers are often thought of as homogenous units, in reality much of the ecological and economic value is found within select hydrological features such as rapids and deep pools.[52] These geomorphological features can have a large impact on the overall biodiversity and ecological health of a river.[53, 54] In addition to individual features, connectivity between river segments, and with the larger Mekong Basin is of critical importance to riverine health.

The Sesan River Basin stretches from Dak Glei Commune, Kon Tum Province in Viet Nam to Stung Trung Province in Cambodia. The Sesan River reaches up to Plei Krong Dam, where it splits into two tributaries: Dak Bla to the east and Krong Poko to the north.[55] In total,

[48] The Kon Tum meteorological monitoring station is not located in Kon Tum town and was previously named Dak Bla.
[49] Hijmans, et al., (2005).
[50] CNMC, 2011, p. 11.
[51] Temperatures here are higher than more mountainous locations in the basin. Source: VNMC, 2010.
[52] Baran, et al., 2011.
[53] Meynell, et al., 2014.
[54] Baran, et al., 2011.
[55] VNMC, 2010, p. 22.

the Sesan River has approximately 2,785 km of stream length, or 19% and 2.3% of the total length of streams in the 3S Basins and Mekong River Basin, respectively.[56] However, most of this is made up of smaller tributaries that are difficult to identify, either having several different names or having no known name. The length of what could be considered the Sesan River proper is approximately 460 km. In the upper reaches the active channel reach (width regularly covered by water) varies, starting from narrow headwater tributaries and reaching wider than 150 m in places. Incised gorges of less than 50 m across can be found in narrower stretches of the river. In addition, hydropower reservoirs have modified width and depth in numerous areas of the Sesan, effectively flooding out the natural channel and forming large areas more reminiscent of a lake, such as above the Yali Falls Hydropower Dam. In Cambodia the river is relatively wide, up to 150–300 m across in places. However, it should be noted that this is made up of a mix of water and sandbars and during the dry season water can cover a smaller width.[57]

A study conducted by Baran, et al., (2011) identified eight ecological zones in the Sesan Basin. From the confluence at Stung Trung up to km 58, the basin is characterised by riverine wetland habitat; it splits from the Sre Pok at km 38. From km 58 to 156 there long sandbanks along the edges of the Sesan River. Heading further upstream, a series of dams are found between km 233 and km 286, where the Yali Falls Dam sits. The reservoir behind the Yali Falls Dam reaches another 23 km upstream (to km 309). Upstream of Plei Krong, at the far upper reaches of the reservoir, the Sesan becomes more reminiscent of a mountainous stream again, with a mix of rocky channels, sand banks, and some small wetland areas.[58]

The Sre Pok River Basin starts where two tributaries, the Krong Ana and Krong Kno, drain large sub-watersheds in the upper portion of the basin. The Sre Pok is joined by the Sesan River in Cambodia and subsequently joins the Mekong River at the town of Stung Treng.[59] The mainstream of the Sre Pok (below Krong Ana) is approximately 260 km, not accounting for detailed meanders. Hydrologically, the Sre Pok is characterised by a dendritic drainage system of many tributaries in its upper reaches. While the smaller, upper tributaries follow steep, somewhat straight paths, the larger ones, such as the Ea Krong begin to widen and follow a more meandering path, a form that continues throughout the rest of the Sre Pok River. Stretches in the upper Sre Pok have been significantly altered by the construction of several hydropower dams, which have filled and changed the original form of the river. For example, reservoirs above Buon Tua Srah, Buon Kuop, and Sre Pok 4 have flooded areas which no longer resemble the original river form. During the course of its path the Sre Pok River also passes through several areas of riffles and sandbars, as well as some rapids, such as near Lumphat Wildlife Sanctuary. Only 11 deep pools were identified within the Sre Pok, much fewer than in the Sesan, but this is to be expected given the Sre Pok's lower elevation gradient.[60]

[56] The total length of streams in a basin can vary by an order of magnitude (or more), depending on the definition of 'stream.' For the purposes of this report, the length of the Sesan is taken from a hydrological analysis of the basin (see Meynell, et al., 2014). Stream length of the Sre Pok was measured and roughly rounded down using spatial data provided by the MRC.
[57] Meynell, et al., 2014.
[58] Baran, et al., 2011.
[59] VNMC, 2010, pg. 5.
[60] CEPA, 2008. *In*: CNMC, 2011, p. 45.

Figure 11: Map of rivers in the 3S Basins

Discharge

The 3S Basins contribute between 18% and 26% of the mean annual discharge to the Mekong River (depending on the year). This discharge enters the Mekong and contributes substantially to the seasonal flow reversal in the Tonle Sap.[61] In the Sesan, discharge peaks at up to 4,500 cubic metres per second (m^3/sec) in September, usually falling to 250 (m^3/s) by March. This flood pulse is important for fisheries as well as for replenishing the sediment and nutrients that make the downstream Mekong Delta so fertile.[62, 63]

The Sre Pok Basin contributes a relatively low amount of water given its size, up to 20.6 km^3 (20 billion m^3) per year at Lumphat, although this is still very significant for the total flows measured at Stung Treng.[64] For reference, the Sekong has an average discharge of 44 km^3 per year, while the much smaller Sesan discharges 25.6 km^3 (at Veun Saï). The amount of water in the Sre Pok River has changed both seasonally and overall. This is a result of 1) abstraction of water from the river for use in irrigation (much of which is lost to evapotranspiration) and 2) a shift in flow patterns resulting from dam operation. These trends may have been driven by an intensification of agriculture (increased number of annual crops, shift from dryland to irrigated agriculture), and to a minor degree, population growth and development of urban areas and industrial plants.[65]

3. Land cover, protection, and biodiversity

3.1. Land cover and land use

National land cover data is available for both Viet Nam and Cambodia. However, different definitions of land cover types and analysis methods make national data hard to compare across boundaries. The official basin-wide land cover dataset from MRC is now out of date and should be seen only as a broad indicator. Actual per cent cover of land cover types has almost certainly changed significantly in the 12 years since this analysis was completed.[66] This is especially likely for cultivated land and forest cover, which are interrelated and are to have greatly changed in recent years.[67] The MRC dataset does not include part of the Sekong Basin, and some other small areas are missing data. As such, the values do not add to 100% in all cases.

As of 2003, the 3S Basins had some of the highest per cent cover of forest of any area in the Lower Mekong Basin. However, this used to be even higher. Over the past 30 years the land cover has changed significantly.[68] Much of the land cover change in recent years has been caused by conversion of natural forest areas to agriculture. The creation of reservoirs for hydropower and irrigation purposes has also converted some previously forested and grassland areas into open water.[69]

In its upper reaches the Sesan River travels through areas of heavily forested land, interspersed with agricultural, urban, and other cleared areas. As it flows towards Cambodia it passes through increasingly agricultural areas, eventually reaching flatter wetland marshes and cropland.

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[61] MRC, 2005.
[62] Baran, et al., 2011.
[63] Cochrane, et al., 2010.
[64] Cochrane, et al., 2010.
[65] ADB, 2010.
[66] CNMC 2011, p. 60.
[67] Ibid., p. 58.
[68] ADB 2010a.
[69] Ibid.

In the Sre Pok, plantation forests covered 1,750 km^2 (nearly 6% of the basin) as of 2003. This figure has since increased, as have agricultural and built-up areas.[70] Much of the land cover change in recent years has been caused by conversion of natural forest areas to industrial plantations and expansion of agriculture. The creation of reservoirs for hydropower and irrigation purposes has also converted some previously forested and grassland areas into open water.[71] These changes have more recently spread throughout the Cambodian portion of the Sre Pok as the country rapidly develops. Despite this pressure, significant areas of the basin are still forested.

[70] GlobCover, 2009.
[71] ADB, 2010.

Figure 12: Map of land cover in the 3S Basins (2003)

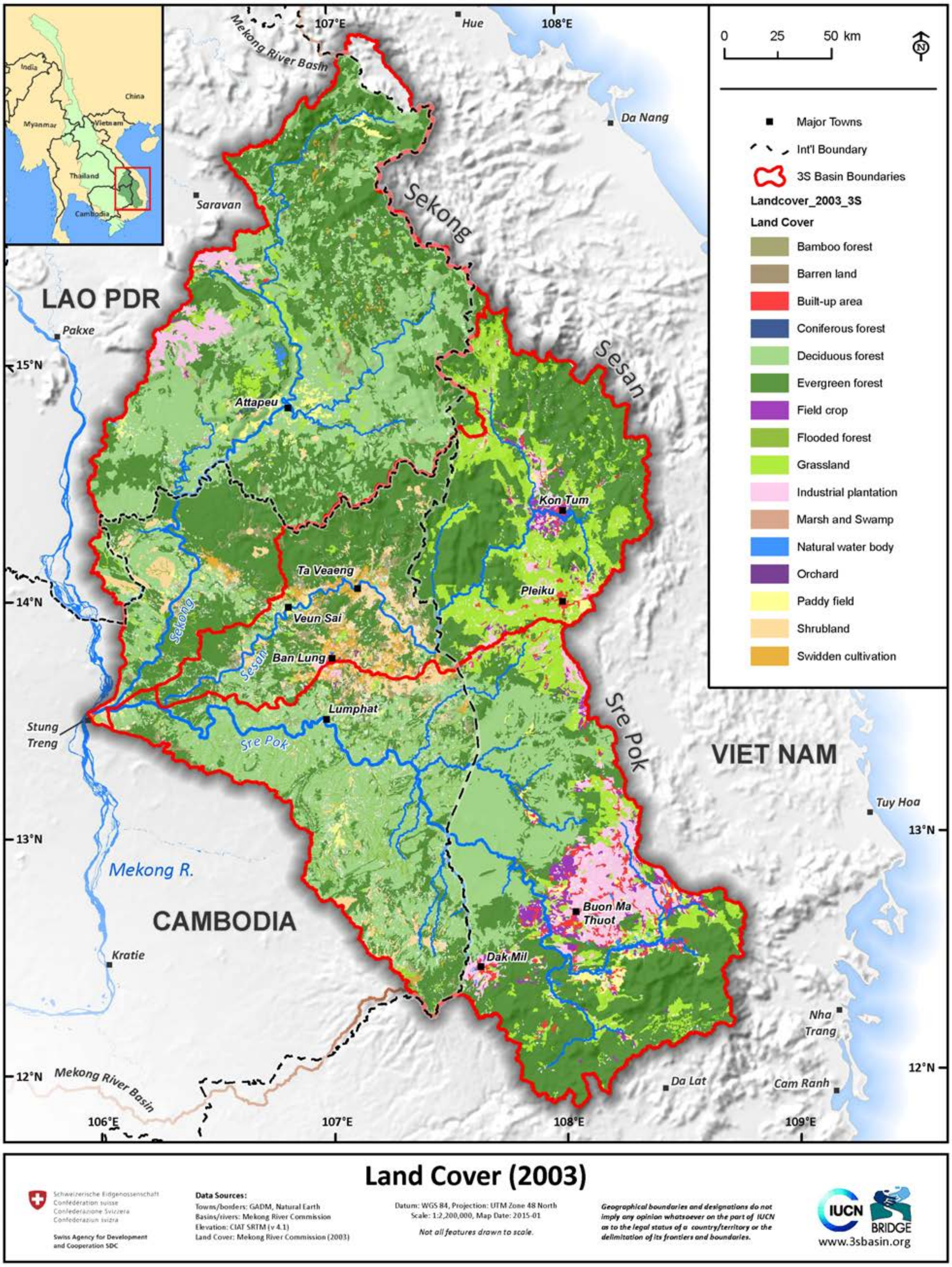

Table 10: Land cover in the Sesan and Sre Pok Basins in 2003[72]

Land Cover	Sesan		Sre Pok	
	Area (km^2)	Per cent of basin	Area (km^2)	Per cent of basin
Bamboo forest	638.0	3.4%	407.5	1.3%
Barren land	3.0	0.0%	-	-
Built-up area	178.0	0.9%	656.9	2.1%
Coniferous forest	-	0.0%		0.0%
Deciduous forest	617.4	3.3%	11,342.8	36.7%
Evergreen forest	10,432.5	55.2%	10,006.2	32.3%
Field crop	263.2	1.4%	685.8	2.2%
Flooded forest	22.3	0.1%	858.9	2.8%
Grassland	3,831.0	20.3%	2,596.9	8.4%
Industrial plantation	230.1	1.2%	1,749.8	5.7%
Marsh and swamp	9.0	0.0%	4.1	0.0%
Natural water body	79.1	0.4%	180.8	0.6%
Orchard	23.0	0.1%	17.3	0.1%
Paddy field	204.7	1.1%	424.4	1.4%
Shrubland	772.8	4.1%	568.1	1.8%
Swidden cultivation	516.2	2.7%	149.9	0.5%
TOTAL*	**18,821.0**	**99.6%**	**30,924.0**	**99.9%**

Agriculture

Cultivated land was estimated to cover nearly 14% of the Sesan in 2003.[73] Major crops in the upper Sesan include rubber, coffee, and cassava. Cassava in particular has expanded markedly in recent years and now makes up around 30% of agricultural land in Kon Tum province and 11% in Gia Lai Province. In turn, this is increasingly transitioning to rubber plantations due to soil erosion impacting areas that previously grew cassava, as well as economic incentives to produce rubber.[74] Numerous irrigation schemes also provide water here, allowing for two crops of rice: a dry season crop from January to April and a wet season crop from July to October.[75] Agricultural land covers a significant portion of the low-lying areas in Cambodia, although information for this part of the basin is more limited. Currently around 7% of the lower Sesan Basin is used for agriculture. Of this, rice is the dominant crop type.[76]

Major crops in the Sre Pok include coffee and cassava. Cultivated land (including plantations) was estimated to cover nearly 12% of the Sre Pok in 2003, a slightly lower proportion than in the Sesan, although the Sre Pok has a larger total area, and the total area cultivated is almost double that of the Sesan (3,500 versus 2,000 km^2).[77] In the Cambodian portion of the basin cultivated land has expanded rapidly over the past three decades: Between 1980 and 2007 the Cambodian Ministry of Agriculture Forestry and Fisheries (MAFF) estimated that area under rice cultivation tripled from 16,403 hectares (ha) to 49,653 ha, an annual increase of 7.5%.[78]

[72] The dominant land cover type is forest which covers more than half of the Sesan Basin. *Total does not add to 100%, due to differences in the boundaries and extent of the watershed and land cover data sets in the Sekong, as originally supplied by MRC. Source: MRC 2003.
[73] JICA, 2002. *In:* CNMC 2001, p. 54. However, this number is significantly higher than estimated by MRC data from the same time period.
[74] Ibid., p. 12.
[75] Olivier, et al., 2013, p. 13.
[76] CNMC, 2001, p. 58.
[77] JICA, 2002. *In:* CNMC 2011, p. 54.
[78] CNMC, p. 58.

Forest

Historically forests likely covered most the Sesan and Sre Pok, but their extent has been reduced from human activities such as clearance for timber and agricultural land. Due to the previous existence of high value timber species and alternative use of low-lying land for agriculture much of the low-lying evergreen forest has been cleared and transformed into land for growing cash crops such as coffee, rubber, and cassava. Low elevation evergreen (and some deciduous) forests support some of the highest recorded species counts, so their loss is particularly significant.[79] Of the remaining deciduous dipterocarp forests in the region, most are found in north-eastern Cambodia and adjacent areas in Viet Nam, overlapping some with the Sesan and Sre Pok.[80]

As of 2003 there were 11,050 km^2 of natural forested land (58.5%) in the Sesan Basin. However, as noted above, this has since decreased. Of the 3S Basins, the Sesan has experienced the highest relative amount of deforestation. A recent study estimates that 9.5% of the basin's forests were lost between 2000 and 2012.[81] Much of the land cover change has been caused by logging for timber, conversion of natural forest areas to industrial plantations, and expansion of agriculture. The creation of reservoirs for hydropower and irrigation purposes has also converted previously forested areas into open water.

In the Sre Pok the majority of deciduous forests are in Cambodia, while remaining evergreen forest can be found in the mountains of Viet Nam. In the area around Buon Ma Thuot there are large areas of plantation forest. These plantation forests cover at least 5.7% of the basin, while the next largest non-forest land cover type is grassland with 8%. As of 2003 there were 22,200 km^2 of natural forested land (71.8%) in the basin, not including plantation forests. A recent global analysis estimated that between 2000 and 2012 around 6% of the forests in the Sre Pok were converted to other land use types.[82]

It is important to note that forest cover does not indicate forest quality. Indeed, under laws in Cambodia and Viet Nam, monoculture forest plantations are considered as a type of forested land, despite their lower ecological value. Of the forest that does remain, some of the highest quality may be in inaccessible highland areas of the basin. In addition, forest cover datasets, by necessity, generalise forest type by broad classes, such as "evergreen" or "mixed deciduous." While these are useful descriptive terms, in reality forests are heterogeneous environments and their classification depends on the exact definition and analysis methods used.[83]

Wetlands

Partially due to the relatively higher slopes in the basins, there are no significant wetland areas in comparison to areas along the mainstream of the Mekong River. However, the numbers cited below are calculated based on spatial data from the MRC which may not include smaller area wetlands. As such, the actual area of wetlands in the Sesan and Sre Pok may be higher than reported here. In the Sesan River Basin the largest wetland areas are along the river in Cambodia's lowlands. Although the Sesan has the third highest proportion of wetland to total basin area of all the major sub-basins in the Mekong, almost all is riverine wetland, following the main branch of the Sesan and covering less than 0.5% of the total basin area.[84] Within these streams 69 deep pools have been identified, which are important for fisheries and other aquatic life.[85]

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[79] CEPF, 2011.
[80] Tordoff, et al., 2005. *In*: CEPF 2011.
[81] Hansen, et al., 2013.
[82] Hansen, et al., 2013.
[83] Rundel, 2009.
[84] Meynell, et al., 2014.
[85] CEPA 2008. *In*: CNMC 2011, p. 45.

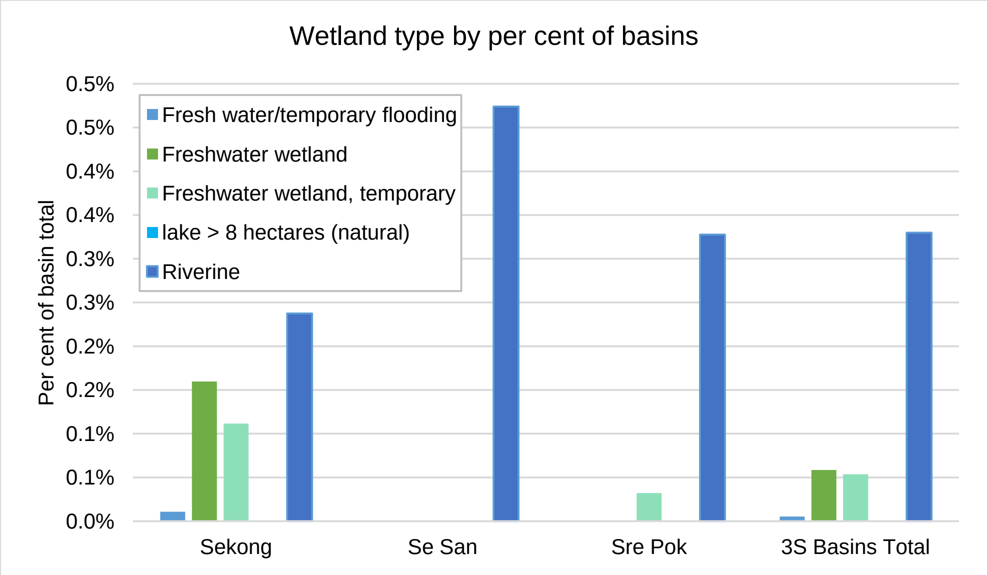
Table 11: Wetland areas in the Sesan and Sre Pok Basins[86]

Wetland Type	Sesan		Sre Pok	
	Area (km^2)	**Per cent of basin**	**Area (km^2)**	**Per cent of basin**
Fresh water/temporary flooding	-	-	1.1	-
Freshwater wetland	-	-	-	-
Freshwater wetland, temporary	-	-	10.0	0.03%
lake > 8 hectares (natural)	-	-	-	-
Riverine	89.5	0.47%	101.4	0.33%
Total	**89.5**	**0.47%**	**112.5**	0.36%

The only sizable wetlands in the Sre Pok Basin are located along the mainstream of the Sre Pok River and in seasonally inundated areas downstream of where the Lower Sesan/Sre Pok 2 Dam is being built. In total these areas cover less than 0.4% of the basin.[87] Overall, aquatic environments cover a small area of the 3S Basins. Looking only at aquatic ecosystems, riverine habitats (e.g., stream and reservoir areas) cover the largest area of the Sre Pok Basin. In the Sre Pok there are 11,500 ha of aquatic ecosystems, which is primarily (60.8%) open water, i.e. river and reservoir areas.[88] In addition, the Sre Pok has a relatively large area of swamp and marshland, which makes up an additional 32.9% of aquatic ecosystem area in the basin.

[86] Open water consists of areas such as rivers and reservoirs. However, data is as of 2003 and therefore does not reflect recent changes. Open water area has likely increased, due to construction of additional reservoirs in the intervening decade. Source: MRC, 2003.
[87] Meynell, et al., 2015.
[88] CNMC, 2011, p. 45.

Figure 13: Wetland types and areas in the 3S Basins[89]



Other land cover types

The next largest land cover types in the basin are grasslands (20%), shrubland (4%), and bamboo forests (3.4%, not included under the forest figures previously stated). Grass and shrubland areas are used for grazing in some areas in the watershed; bamboo provides important non-timber forest products (NTFPs).[90] Although not a major land cover in terms of area, freshwater habitat and sand and gravel bars play an important role for aquatic and birdlife. In the upper reaches of the Sesan gravel bars are more prevalent and often have low shrub growth which makes an ideal habitat for some bird species. In lower areas sandbars dominate and generally have little visible growth.[91]

3.2. Protected areas

The designation of a protected area (PA) can indicate potential ecological value and enhanced management of an area. However, their actual value depends on the reason for creation, effective management, and enforcement of regulations. Although many protected areas already exist in the Sesan and Sre Pok, there are opportunities for improving management as well as for enhanced trans-boundary cooperation.

Sesan Basin

Within the Sesan River Basin there are five major PAs.[92] These include Virachey National Park, Chu Mom Ray National Park, Bac Plei Ku Nature Reserve, and small overlaps with Kon Ka Kinh National Park and Ngoc Linh Nature Reserve. In total, these PAs cover 3,070 km^2 (16.3%) of the Sesan Basin. Some of these overlap with areas outside of the Sesan; areas reported are only for the portion overlapping with the Sesan Basin.

[89] MRC, 2009.
[90] Someth, et al., 2013, p. 27.
[91] BirdLife International. KH011: Sesan River. <http://www.birdlife.org/datazone/sitefactsheet.php?id=16662>. Accessed 9 May 2014.
[92] IUCN and UNEP 2013.

Table 12: Major protected areas in the Sesan Basin[93]

Protected Area	Sesan	
	Area (km^2)	Per cent of basin
Cambodia	-	-
Virachey NP	2,271	12%
Viet Nam	-	-
Chu Mom Ray NP	523	2.8%
Bac Plei Ku NR	140	0.7%
Kon Ka Kinh NP	111	0.6%
Ngoc Linh NR	55	0.3%
Total	3,070	16.3%

BirdLife International has identified several Important Bird Areas (IBAs) in the region. IBAs are defined as areas that are globally crucial for the continued survival of bird populations and can, but do not necessarily, overlap with legally protected areas. IBAs in or adjacent to the Sesan are listed below.

Table 13: Important Bird Areas overlapping or adjacent with the Sesan Basin[94]

IBA	Location	Bird species of interest and their classifications according to the IUCN Red List of Threatened Species™
Sesan River	Riparian areas of Ratanakiri and Stung Treng provinces, Cambodia, along entire riparian stretch of Sesan River in Cambodia	White-rumped vulture (*Gyps bengalensis*) (CR), lesser adjutant (*Leptoptilos javanicus*) (VU), river lapwing (*Vanellus duvaucelii*) (NT)
Kontum Plateau (secondary area)	Area surrounding Kon Tum City, Viet Nam	Crested argus (*Rheinardia ocellata*) (NT), grey-faced tit-babbler (*Macronous kelleyi*) (LC), white-cheeked laughing thrush (*Garrulax vassali*) (LC)
Kon Cha Rang	12 km east of Kon Cha Rang Nature Reserve (adjacent to eastern border of Sesan Basin)	Masked finfoot (*Heliopais personatus*) (E), great hornbill (*Buceros bicornis*) (NT), short-tailed scimitar-babbler (*Jabouilleia danjoui*) (NT)
Ngoc Linh	Mt. Ngoc Linh, Kon Tum and Quang Nam Provinces, Viet Nam. The IBA overlaps with 13,000 ha of the Ngoc Linh (Kon Tum) Nature Reserve, on the north-eastern border of the Sesan Basin	Crested argus (*Rheinardia ocellata*) (NT), black-crowned barwing (*Actinodura Sodangorum*) (NT), golden-winged laughingthrush (*Garrulax ngoclinhensis*) (VU)
Kon Ka Kinh	12 km west of Kon Cha Rang Nature Reserve, Gia Lai, Viet Nam. The IBA is identical in extent to the 41,000 ha Kon Ka Kinh National Park, in the eastern highlands of the basin	Chestnut-eared laughingthrush (*Garrulax konkakinhensis*) (VU), grey-faced tit-babbler (*Macronous kelleyi*) (LC), white-cheeked laughingthrush (*Garrulax Vassal*) (LC).

[93] Only area contained within the basin boundaries shown here. Source: WDPA 2013.
[94] NT = near threatened, VU = vulnerable, LC = least concern. Source: BirdLife International.

The lower Sesan River IBA was assessed in 2003 and was found to be one of the best remaining lowland river bird communities in Indochina. Species observed here include the critically endangered white-rumped vulture (*Gyps bangalensis*) and vulnerable lesser adjutant (*Leptoptilos javanicus*). It is assumed that most common bird species, and many rarer ones, found in similar habitats in the region would also be found in the Sesan. For example, the long-tailed macaque (*Macaca fascicularis*) and crested langur (*Semnopithecus cristatus*) are thought to be present to some degree in the basin, based on habitat type requirements.[95]

Kon Ka Kinh IBA/National Park is of special interest for its biological diversity and value. In addition to important bird species, several endangered and threatened mammals are found here. These include the endangered Truong Son muntjac (*Muntiacus truongsonensis*), the globally threatened grey-shanked douc langur (*Pygathrix nemaeus cinereus*), the stump-tailed macaque (*Macaca arctiodes*), and the yellow-cheeked crested gibbon (*Nomascus gabriellae*). Additional species reportedly found here, but without confirmed population numbers, are the moon bear (*Ursus thibetanus*), the Indochinese (or Sumatran) serow (*Naemorhedus sumatraensis*), and the tiger (*Panthera tigris*).[96] The presence of so many endangered and threatened species here makes it particularly important for ensuring these populations are protected in the Sesan Basin.

Sre Pok Basin

Within the Sre Pok River Basin there are fifteen significant PAs[97]. The largest of these include Yok Don National Park and Mondulkiri Protected Forest. As with the Sesan, the numbers reported below are only for areas overlapping with the Sre Pok Basin, but some of these extend to areas beyond the watershed. In total, approximately 41% of the Cambodian portion is protected, while 30% of the area in Viet Nam falls within a protected area.

[95] BirdLife International. KH011: Sesan River. <http://www.birdlife.org/datazone/sitefactsheet.php?id=16662>. Accessed 9 May 2014.
[96] BirdLife International, 2014.
[97] IUCN and UNEP, 2013.

Table 14: Major protected areas in the Sre Pok Basin

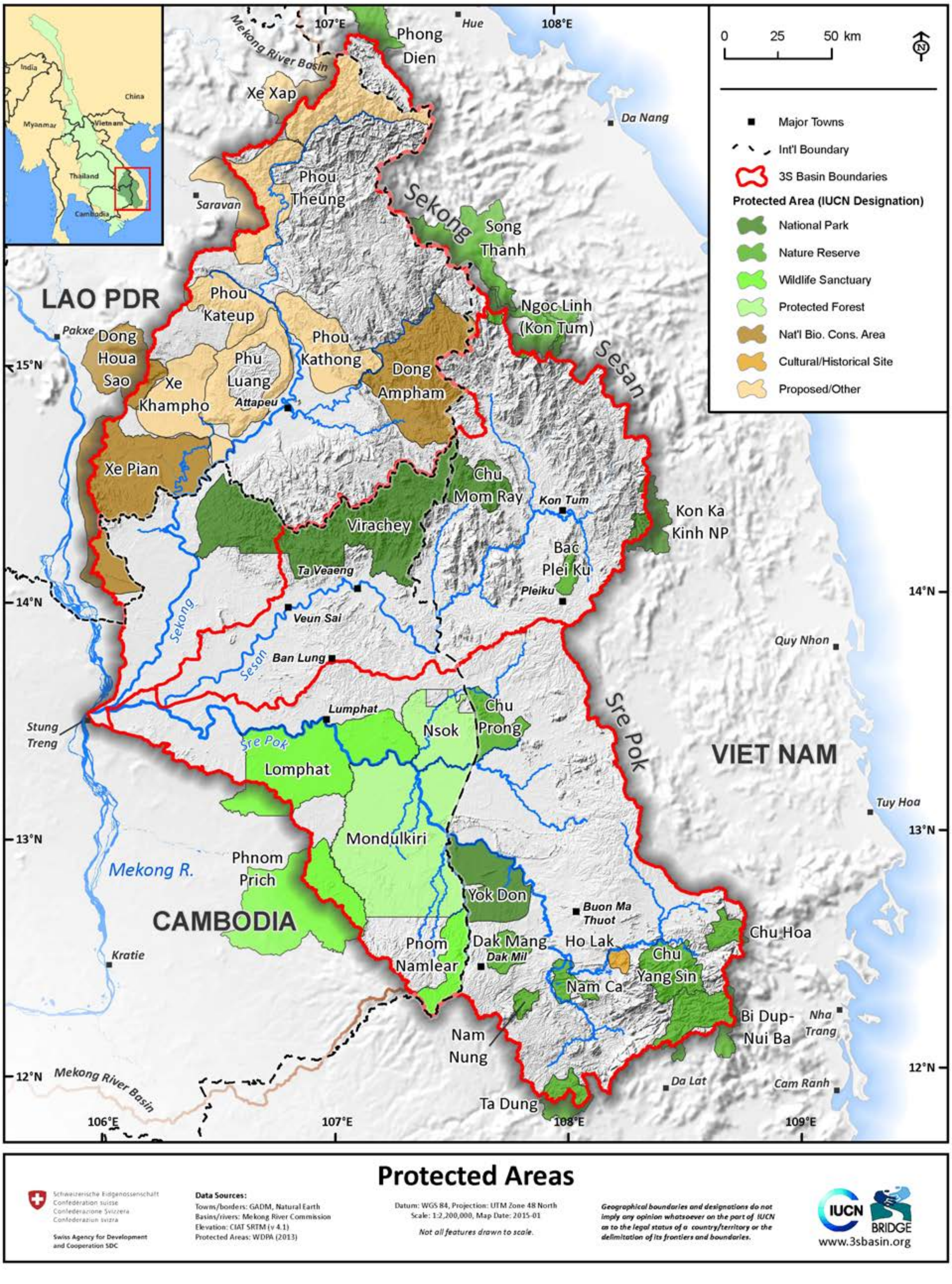
Protected Areas	Area*	
	Area (km^2)	% of basin
Cambodia	-	-
Lumphat NP	2,181	7.1%
Nsok PF	940	3.0%
Mondulkiri PF	3,709	12.0%
Phnom Prich WS	523	1.7%
Phnom Namlear WS	504	1.6%
Viet Nam	-	-
Bidoup-Nui Ba NP	525	1.7%
Chu Hoa NR (proposed)	188	0.6%
Chu Prong NR (proposed)	474	1.5%
Chu Yang Sin NR	589	1.9%
Dak Mang NR (proposed)	289	0.9%
Ho Lak	98	0.3%
Nam Ca NR	241	0.8%
Nam Nung NR	105	0.3%
Ta Dung (proposed)	191	0.6%
Yok Don NP	1014	3.3%
TOTAL	**11,571**	**37.4%**

A table of IBAs and select species of interest in the Sre Pok is included below.

Table 15: IBAs overlapping with the Sre Pok Basin

IBA	Location	Critically Endangered bird species of interest
Upper Sre Pok	Sub-catchment upstream of Lumphat town, overlapping with part of Phnom Prich (Prech) WS and Lumphat NP.	White-shouldered ibis (*Pseudibis davisoni*), giant ibis (*Thaumatibis gigantean*), white-rumped vulture *(Gyps bengalensis*), red-headed vulture (*Sarcogyps calvus*), slender-billed vulture (*Gyps tenuirostris*)
Mondulkiri-Kratie Lowlands	Large lowland area in south-western Mondulkiri province, west of Buon Ma Thuot.	White-rumped vulture (*Gyps bengalensis*), red-headed vulture (*Sarcogyps calvus*)
Lomphat (Lumphat)	Contiguous area of deciduous dipterocarp forest extending from Lumphat WS to the Sre Pok-Sesan confluence.	White-rumped vulture (*Gyps bengalensis*), red-headed Vulture (*Sarcogyps calvus*), slender-billed Vulture (*Gyps tenuirostris*)

Figure 14: Map of protected areas in the 3S Basins



3.3. Biodiversity

The Indo-Burma hotspot, an area covering a similar area to the Greater Mekong Sub-region, is one of the most biodiverse and threatened areas in the world. A ranking by Conservation International places it in the top ten places in the world for the irreplaceability of its species, and in the top five in terms of threats.[98] Within this area, four priority corridors have been identified as a special focus, including the Mekong River and its tributaries. As some of the most important tributaries to the Mekong, the Sesan and Sre Pok Rivers are thus also high priorities for biodiversity conservation. The Critical Ecosystem Partnership Fund (CEPF) identified riparian areas within the Sesan, and the entire lower Sre Pok, as priorities for biodiversity conservation.[99]

The Sesan is home to a variety of other flora and fauna species, including several endemic to the region (there are no known species endemic to only the Sesan Basin). A literature review conducted by the World Wide Fund for Nature (WWF) found 367 new species in the greater Mekong region in 2012–2013.[100] Of these, 131 were discovered in Viet Nam and Lao PDR. Recorded species of special interest include the sambar (*Cervus unicolor*, a type of deer), and the buff-cheeked gibbon (*Nomascus gabriellae*). Charismatic megafauna such as the Asian elephant (*Elephas maximus)* and tiger (*Panthera tigris*) have been recorded as living in protected areas in the past, such as in Virachey National Park. However, it is debatable if any remain in the wild. Species such as the saola (*Pseudoryx nghetinhensis*), which is found only in the Annamite Mountains of Viet Nam and Lao PDR, have declined precipitously and the exact number of individuals living in the Sesan Basin is unknown.

Fish and aquatic life

The Mekong River is renowned as one of the most biodiverse and productive freshwater river systems on the planet. Its waters are home to 781 fish species, which provide up to two-thirds of the protein consumed by people living within the basin.[101] The 3S Basins are home to 42% (329) of the total fish species found in the Mekong. This is notable given that 3S Basins are roughly one-tenth the size of the Mekong. Of the species found in the 3S, at least 89 (66%) are migratory and depend on connectivity to adjacent areas.[102] At least 30 of these species migrate between Tonle Sap Lake and the Sesan and Sre Pok and form an important part of the basins' ecology.[103] Between May and August, when river levels rise, these species move between the basins, Mekong River, and Tonle Sap to spawn. During the dry season migratory fish take refuge in deep water pools in the Mekong, and to some degree, in the Sesan and Sre Pok.

Within the Sesan Basin 133 fish species have been recorded.[104] While a relatively large number of species, given the basin's size, it is around 50% less than the number of species found in the Sre Pok Basin. Interestingly, there are no known endemic species found only within the Sesan. This may be due to the interconnectedness with the Sre Pok Basin and similarities in habitat between areas within all three of the 3S Basins. Within the Sre Pok Basin 240 fish species have been recorded. This is the highest number in any of the 3S Basins and represents nearly 73% of the number of species found in the entire Mekong Basin.

[98] Conservation International, 2011.
[99] For more information see http://www.cepf.net/
[100] WWF, 2014.
[101] Hortle, 2007.
[102] Baran, et al., 2013.
[103] Baird, et al., 2003.
[104] Baran, et al., 2013.

Table 16: Number of fish species recorded in the 3S Basins[105]

Basin	Fish species	Per cent Mekong species	Fish families	Per cent total
Sekong	213	64.7%	33	37.1%
Sesan	133	40.4%	26	29.2%
Sre Pok	240	72.9%	33	37.1%
Total	**329**	**-**	**89**	**-**

There are at least 14 endangered fish species in the Sesan, including Critically Endangered species like the giant catfish (*Pangasianodon gigas*), giant carp (*Catlocarpio siamensis*), and giant salmon carp (*Aaptosyax grypus*). Large fish species such as these have been particularly hard hit and they are now rare in the Sesan Basin.[106] Based on habitat range and sightings elsewhere Jullien's golden carp (*Probarbus jullieni*) and pangasius (*Pangasius sanitwongsei*), both on IUCN's Red List, are also thought to occur in the Sesan River. In addition to these fish species, Siamese crocodiles (*Crocodylus siamensis*) may also make their home in some areas in the basin, although there are no known population centres.[107]

4. Population, socio-economic development, and human health

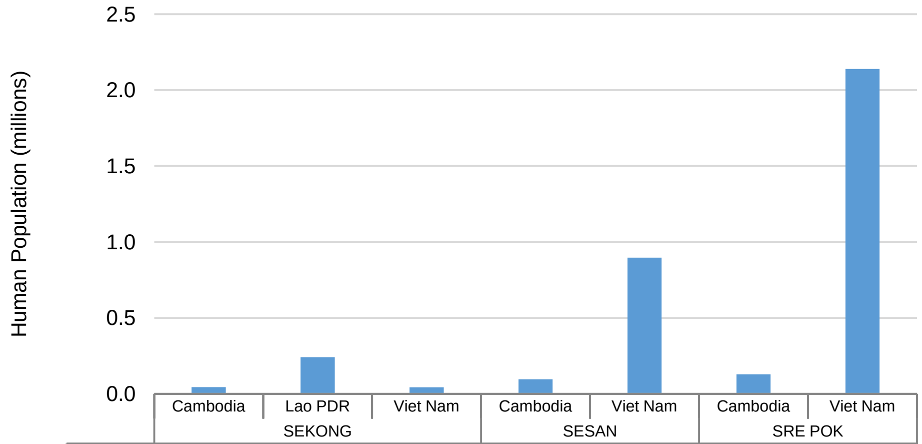
4.1. Population

Population and demographics in the Sesan and Sre Pok vary considerably by country and location within the basins. In general, population is concentrated along riparian areas and some of the large valleys, with Viet Nam having a much higher population than Cambodia.[108, 109] The basins, and more generally, the Central Highlands, have been subject to government migration incentives, which has increased the population, development, and accompanying demands. For example, between 2006 and 2010 the population of Pleiku, Viet Nam increased by over 85,000 people.[110]

Population figures were obtained from national Mekong Committee reports as well as calculated from data obtained from LandScan.[111] LandScan is a dataset that provides an estimate of population, based on a variety of inputs, including national census data, land cover and terrain, and remote sensing imagery. Although population data is also available from the governments of Cambodia and Viet Nam, the most accessible datasets (for example those published by the MRC) only show population at the province or district level. By using LandScan it is possible to accurately estimate population by basin and illustrate distribution patterns.

[105] Modified from Baran, et al., 2013.
[106] Ibid.
[107] BirdLife International. KH011: Sesan River.
[108] CNMC, 2011, p. 11.
[109] VNMC, 2011, p. 24.
[110] Ibid.
[111] LandScan, 2012. For more information, see: http://web.ornl.gov/sci/landscan/. In this section population numbers are reported from both national census data and LandScan, depending on the area and data sources available.

Figure 15: Population in the 3S Basins[112]



	SEKONG			SESAN		SRE POK	
	Cambodia	Lao PDR	Viet Nam	Cambodia	Viet Nam	Cambodia	Viet Nam
Population	44,316	241,677	43,183	95,603	896,812	128,074	2,139,471

Sesan

In the Sesan, Cambodia has a population density of less than 10 people/km^2 in much of Stung Treng and Ratanakiri provinces (but this exceeds 100 people/km^2 around the town of Ban Lung).[113] In the Cambodian portion of the basin there are 19,315 households, at an average size of five people per household, or approximately 95,000 people total.[114] This is predicted to increase to over 140,000 by the year 2060 (a doubling of the year 2007 population).[115] Population is concentrated in provincial towns and is overwhelmingly young (43% are below 15 years old).[116] Viet Nam has a higher population density with over 200 people/km^2 in Gia Lai province; Kon Tum is significantly lower at 46 people/km^2.[117] In sub-area 7V, which includes the area of both the Sesan and Sre Pok within Viet Nam, population density averages 100 people/km^2 which is around 35% Viet Nam's average.[118]

Major towns in the Sesan include Ban Lung and Stung Treng in Cambodia and Pleiku and Kon Tum in Viet Nam. Population growth in the basin is high, exceeding 1% in all provinces and above 3% in Ratanakiri.[119] There are 37 ethnic groups living in the Sesan Basin, with the Kinh making up a little over half of people living in the Sesan within Viet Nam. Ethnic minority groups include the Gia Rai (17%), Xe Dang (12%), Ba Na (9%), and Gie Trieng (4%).[120] Nationally, the majority of the population in Cambodia belong to the Khmer ethnicity. However, in the 3S Basins other ethnic groups make up a large proportion of the population.[121] The Khmer are in the minority here, numbering 14,154 people or 18% of the population. Minority groups include the Cham, Kachak, Kroeung, Lao and Tompuon, among others.[122]

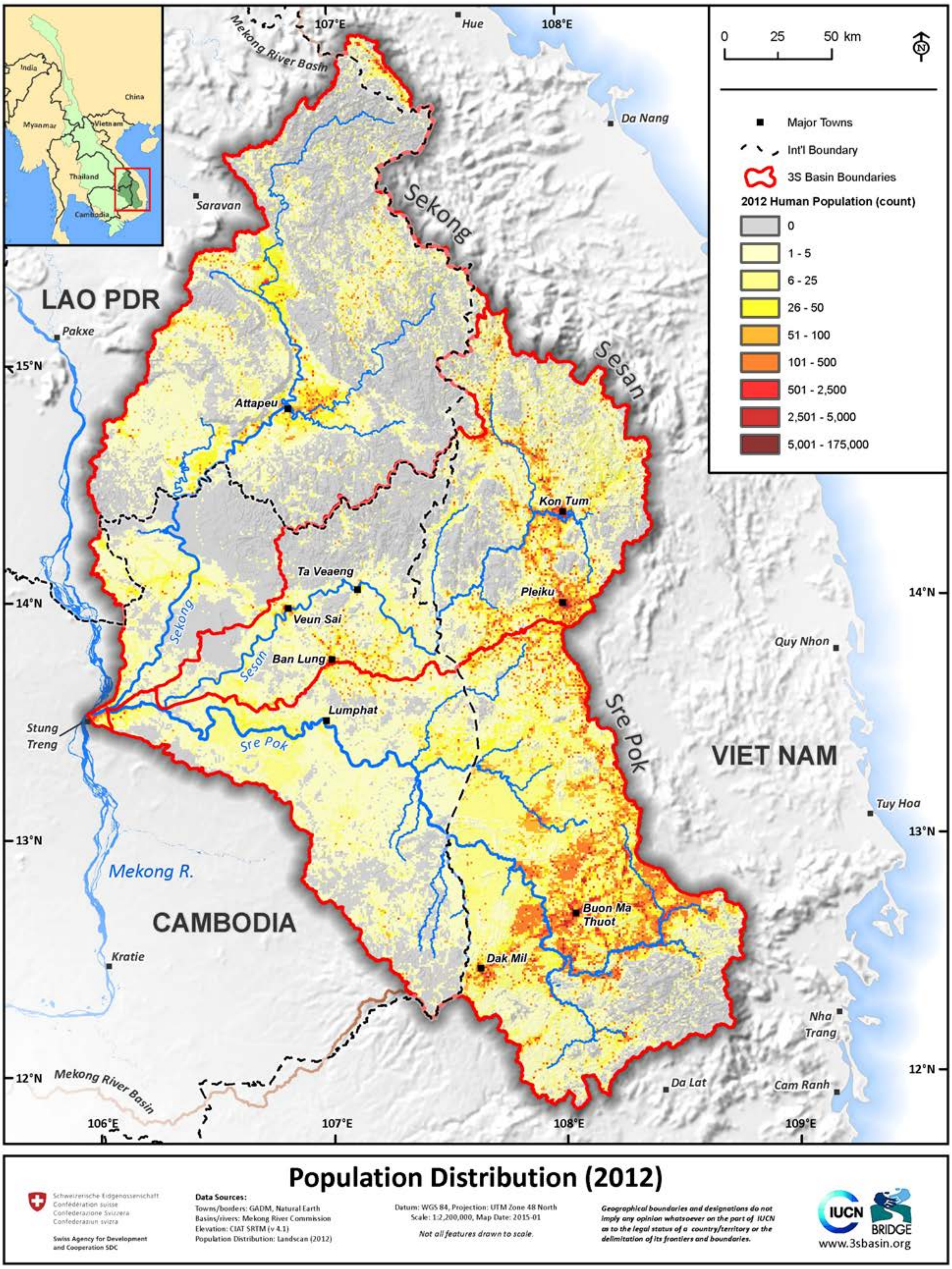
[112] Ibid.
[113] CNMC, 2011, p. 16
[114] Cambodia General Population Census 2008.
[115] CNMC, 2011, p. 80.
[116] CNMC, 2009.
[117] Hong, et al., 2013.
[118] VNMC, 2010, p. 91.
[119] General Population Census of Cambodia, 2008.
[120] VNMC, 2010, p. 93.
[121] CNMC, 2011, p. 16.
[122] Ibid.

Sre Pok

The Sre Pok is by far the most populated of the 3S Basins. Of the nearly 4.7 million residents in the 3S, 2.9 million (61%) call the Sre Pok home. Of the population in the Sre Pok 94% live in Viet Nam. Population is concentrated around the provincial capital of Buon Ma Thuot, Dak Mil, and along transportation corridors. Population density is similarly divided: at 118 people/km^2 in Viet Nam, more than 10 times the density in Cambodia.[123] In Cambodia, the population is growing at 1.7% per year. Similarly Viet Nam has seen large population increases due to migration.

[123]Landscan, 2012.

Figure16: Map of population distribution in the 3S Basins



4.2. Socio-economic development

During much of the 20th century, Cambodia and Viet Nam have been listed as developing countries, characterised by low Gross Domestic Product (GDP), high rates of poverty, and heavy dependence on natural resources. Starting in the mid-1980s Viet Nam implemented a series of economic reforms known as *doi moi* ("renovation"), which initiated the country's transition to what the government calls a "socialist-oriented market economy." Cambodia started its economic transition in 1995 towards a more market-oriented economy. In recent years both countries have experienced rapid development, with Viet Nam moving into middle income country status. Viet Nam was growing at 5.5% in the first part of 2014, and is projected to rise to 6.0% by 2016.[124] Cambodia had a 7.2% growth rate in early 2014, which is expected to slightly decrease in the future.[125] Agriculture is expected to continue to play an important role in poverty reduction in rural areas since most poor live in rural areas and are highly dependent on agriculture.[126]

As of 2009 the annual income in Cambodia's Stung Treng province was USD290 per household. However, this extremely low number does not necessarily reflect living conditions, since the rural economy does not run exclusively on cash. Families with land holdings can grow their own food, fish, hunt, and obtain some natural resources without need for currency. Still, this figure is considered very low both globally and within Cambodia. Livelihoods in Cambodia's portion of the Sesan and Sre Pok depend heavily on rain-fed agriculture (due to little irrigation capacity), fishing, and collection of non-timber forest products (NTFPs).[127] Livelihoods here, and to a slightly lesser degree in Viet Nam, are highly dependent on natural resources. In the Cambodian portion of the 3S Basins, it is estimated that annual revenue related to water and associated resources is USD10 million, of which 91% comes from freshwater fisheries.[128] In contrast, irrigated rice production was estimated to bring in less than USD120,000 per year, or just over 1% of revenue for the area. The exact balance between different sectors depends heavily on hydropower and the availability of water for irrigation, so this has likely changed and will change further in the future. In Viet Nam yearly income in the Sesan was higher for the same year, at USD660 annual per capita, with a large gap between rural and urban residents.

Yearly income in the Viet Nam portion of the Sre Pok is higher, with a large gap between rural and urban residents and between different districts. Around 40% of the population here is in the labour force. Of this, 84% work in agro-forestry operations, and around 5% are unemployed. Livelihoods are highly dependent on natural resources. As such, the health of the natural ecosystem of the basin affects livelihoods, especially of the poorest. The official poverty rate decreased from 28.5% in 2005 to 15.5% in 2008, although a few districts in the area remain among the poorest in Viet Nam.[129, 130]

Agriculture

Agriculture is the most widely practiced livelihood in the Sesan and Sre Pok. Both permanent and slash and burn cultivation is practiced, although the latter has decreased in prevalence. Crops grown in the Sesan include rice, taro, cassava, coffee, and orchards. Cash crops include rubber trees, soybean, groundnuts (peanut), and sesame.[131] In Cambodia a lack of irrigation infrastructure means crops like rice are not grown at as large a scale as might be expected during the dry season. During the wet season Cambodia grows 10,400 ha of the crop in the Sesan.[132] An additional 44,000 ha of rice are grown in Viet Nam, although this is

[124] http://data.worldbank.org/country/vietnam
[125] http://data.worldbank.org/country/cambodia
[126] World Bank, 2009. *In*: CNMC, 2011, p. 124.
[127] CNMC, 2011, p. 11.
[128] CNMC, 2011, p. 50.
[129] Hong, et al., 2013.
[130] VNMC, 2010, p. 93.
[131] Someth, et al., 2013.
[132] National Committee for Sub-National Democratic Development (NCDD) of Mondulkiri. Mondulkiri Data Book 2009.

second to cassava which is grown on 53,000 ha.[133] In the Viet Nam portion of the basin, more than half of GDP comes from agriculture and related activities.[134] The agriculture and forestry sectors together employ 84% of labourers in the area.[135]

Crops grown in the Sre Pok include coffee, pepper, taro, cassava, and orchards (such as cashew). Cash crops include rubber and other tree plantations which have spread across large areas of the basin.[136] Around 90% of the population in Cambodia depends on agriculture for food and income. Yet, only 3.6% of the catchment area is used for agricultural cultivation. This includes 21,000 ha of rice, nearly 4,000 ha of cash crops, and 2,500 ha of orchards.[137] Additional economic and livelihood contributions come from non-timber forest products and other natural resources. NTFPs include materials such as rattan (used in producing furniture and handicrafts), as well as cash crops like cardamom, and medicinal herbs and materials such as hemp vine.

Fisheries

The exact levels of fish catch in the Sesan and Sre Pok remain unknown because the fisheries are small in scale (individual fisherfolk) and distributed in nature. However, it is known that river communities in the two basins depend heavily on fish for a source of protein and, in some areas, for a significant part of their income. As shown in the table below, fish catch has been declining in recent years, although this is likely more due to increasing human populations rather than decreasing fish populations. The Sekong Basin is included for reference, showing the significantly higher per capita fish catch within that basin. Nevertheless, fisheries face a combination of real threats. These include changes to the natural environment and flow patterns, land cover change and modification of floodplains, and overexploitation of fisheries resulting in decreased fish population.[138] Climate change has also been identified as a potential threat to fisheries and livelihoods, primarily through predicted changes to precipitation and runoff.

Table 17: Per capita annual fish catch in the 3S Basins[139]

	Fish catch (kg/person/year)		
Year	**Sekong**	**Sesan**	**Sre Pok**
2002	141.7	18.2	29.1
2003	113.3	15.1	25.1
2004	87.2	10.8	18.6
2007	32.7	4.4	4.4
2008	104.6	12.5	12.2
2009	119.9	12.3	12
Mean	99.9	12.2	16.9

In the Sesan Basin hundreds of thousands of people live along or within a few kilometres the Sesan River. The majority of these are in Viet Nam and are not believed to be as dependent on fish as the 30,000–60,000 people living in Cambodia's riparian area.[140] These Cambodian communities depend heavily on the Sesan fishery as a source of protein, but even here the exact numbers are unknown and depend on factors such as distance to the river and wealth. Although the local fishery is undoubtedly important for both socio-economic

[133] Hong, et al., 2013.
[134] Neishem, 2008.
[135] VNMC, 2010, p. 92.
[136] Someth, et al., 2013.
[137] CNMC, 2011, p. 129.
[138] CNMC, 2011, p. 123.
[139] Baran, et al., 2011.
[140] Ibid.

and ecological reasons, there is a wide range of estimates for catch, with a magnitude of order between different data sources. In sub-area 7C one study valued fisheries and wetlands at USD2.6 million per annum. However, this is an estimate and the actual figures could be much higher.[141]

In Viet Nam little data exists on production and economic value of the catch for local residents of the Sesan, making it difficult to determine the magnitude of change in fish populations. However, interviews in the basin conducted by the Viet Nam National Mekong Committee indicate that both fish catch and average fish size have decreased since 2005.[142] Up to 80% of fish may now be caught in reservoirs rather than natural streams, and the government has introduced breeding programmes in these areas.[143]

Education

Educational attainment in the Sesan and Sre Pok starkly differ between the two countries, but are biased by the unit of analysis. In Viet Nam educational figures have been reported as national averages, as aggregated by MRC. According to this data, more than 80% of the primary age students are enrolled in school, and this approaches 100% in some areas.[144] In Cambodia, school enrolment is low: below 60% in Stung Treng Province and falling below 40% in Ratanakiri.[145] In Cambodia half of all 15–60 year olds in the Sesan are illiterate. Secondary school enrolment follows similar trends, although is lower in both countries. In Viet Nam at least 50% of all secondary age students are enrolled in school, while in Cambodia this falls to below 20% in Stung Treng and is less than 10% in Ratanakiri. Potential reasons cited for lower educational attainment in Cambodia include distance to schools, instruction in Khmer (a second language for many), expense of books and materials, need for labour within the family, and frequently absent teachers.[146]

Electricity access

Economic growth has brought much needed foreign investment and helped lift millions of people in the region out of poverty. At the same time it has increased demand for key natural resources and electricity. Cambodia and Viet Nam's electricity demand is expected to greatly increase in the coming decades.

In Viet Nam, power demand increased by 400% between 1990 and 2008 and is expected to continue growing by 10% per year through 2020.[147] Cambodia faces an even more acute power shortage, with only a quarter of the population having access to grid electricity (a figure that falls below 13% in rural areas). As much of 90% of Cambodia's power supply is currently generated by expensive imported fuels such as diesel. In the Sesan, access to reliable power is rare outside of sizable towns such as Ban Lung. Cambodia's National Strategic Development Plan calls for increased energy supply and reliability, with a goal to bring electricity to 100% of villages by 2020. In practice, this has meant a strong focus on hydropower. If it meets its target, nearly 70% of Cambodia's 6,000 megawatt (MW) power production capacity will come from hydropower, much of it in the northeast, including in the Sesan and Sre Pok Basins. In provinces in the region access to grid electricity is below 40%, although this is skewed by a few larger towns and would otherwise be even lower. In rural areas grid connectivity approaches zero in places. This is in stark contrast to Viet Nam where more than 90% of the population in the Sesan and Sre Pok is reported to have electricity access.[148]

[141] VNMC, 2010, p. 18.
[142] VNMC, 2010, p. 65.
[143] Ibid.
[144] UNICEF, 2014.
[145] World Food Programme, 2014.
[146] CNMC, 2011, p. 108.
[147] Economic Consulting Associates, 2010.
[148] MRC, 2009 [database].

Water access
Access to improved water sources is limited in rural areas of Cambodia.[149] In both provinces in the Sesan access is between 20% and 40%; in the Sre Pok access is below 35% and falls to below 25% in Stung Treng Province.[150, 151] In both basins in Viet Nam the access rate is between 80% and 90%.[152] In Ratanakiri and Stung Treng provinces in Cambodia 61% of residents obtain water from springs, the Sesan or Sre Pok Rivers, smaller streams, or from rain. Another 32% use well water and only 5.5% use water that is treated (either purchased, piped water or from tube wells).[153, 154] Access to piped and treated water sources is extremely low and essentially only accessible to a sub-set of residents living in provincial towns. Access to water for irrigation is similarly low (see section 5.2). Of note, ground water resources are not well understood in the region, but are thought to be rapidly declining in many areas. The only known field study on groundwater in this area was conducted as part of the EIA for the Lower Sesan/Sre Pok 2 Hydropower Dam.[155] An academic thesis conducted on the subject estimated potential annual groundwater reserves in the upper Sesan (Viet Nam) at 2,235 million cubic meters.[156]

Sanitation access
Sanitation access has lagged behind access to improved water supplies and other development metrics. In Cambodia's territory in the Sesan less than 8% of households have a flush/non-flush toilet or latrine in their home; in the Sre Pok less than 2,100 households have a toilet or latrine in their home.[157] Viet Nam fares better at 40–60% in both basins. Access to sanitation is an important metric because it is often correlated with health. It is unclear what relative threat this plays in the Sesan or Sre Pok Basin. However, given low rates of access to sanitation, it is reasonable to assume that one of the persistent low level threats to human health is river water contaminated with faecal coliforms. Heavy metals are another potential impact to human health. A study in Cambodia found that in populations where fish is a major source of protein there were no clear health impacts or widespread contamination, despite mercury being above guidelines in some species (see following section).[158] However, more data may be needed to fully understand this potential threat.

4.3. Human health

Health and educational development in the Sesan Basin lag behind the major urban centres in Cambodia and Viet Nam. Viet Nam has made gains in nutrition and meeting calorific needs of its population. However, in Stung Treng Province approximately 40% of children have stunted growth due to poor nutrition. This is due to factors such as low income, inadequate access to land and fisheries, and the related factor of resettlement. In the Sesan around 7% of the Cambodian population has land holdings less than 1 ha, with an additional 8% having no land for rice cultivation.[159]

Water quality
There are no specific water quality objectives for the LMB, but water measurements are taken to record trends and identify emerging issues of concern.[160] Water quality within the

[149] Defined as water from a pipe, tube, or protected dug well in Cambodia and as a private tap, public tap, well with pump, or hand-dug well (no pump), or rainwater in Viet Nam.
[150] General Population Census of Cambodia, 2008.
[151] CNMC, 2009.
[152] GSO Viet Nam, 2010.
[153] ADB, 2010b.
[154] ADB, 2010c.
[155] CNMC, 2011, p. 19.
[156] "Study into scientific bases [sic] and proposal of rational protection and use measures for the Central Highlands". Thesis KC 08.05, University of Mines and Geology. *In*: VNMC, 2010, p. 71.
[157] CNMC, 2009.
[158] Agusa, et al., 2005.
[159] CNMC, 2011, p. 111.
[160] ADB, 2010, p. 16.

LMB has been measured at approximately 100 sampling sites since 1985 (sites in Cambodia were added in 1993). However, only 48 have long term records.[161] Of these, 17 are used for calculating an annual Water Quality Index (WQI), based on a combination of parameters. Since most of the MRC's water sampling sites are on the mainstream of the Mekong River, water quality data for the Sesan and Sre Pok Basins is limited. However, during a study in the 2003 and 2004 dry seasons, samples in all of the 3S Basins were taken for heavy metals and other contaminants. The Sekong and Sre Pok Basin were both sampled in 2003. The Sesan Basin was sampled in 2004 (but not 2003).[162] Follow-up sampling events from 2004 to 2008 attempted to capture inter-annual variability in water quality (see table 18, *below*). All of the 3S Basins were classified as being only "impacted" by human activity and "slightly impacted" by land uses such as agriculture and livestock (most sampling locations in the LMB are classified as "severely impacted").[163]

Table 18: Parameterised water quality ranking for the 3S Basins[164]

		Sampling Year				
River	Site Code	2004	2005	2006	2007	2008
Sekong	LKL	-	A	-	C	C
"	CKM	-	A	B	B	A
Sesan	CSU	-	A	B	B	A
"	CSJ	-	A	B	A	A
Sre Pok	CSP	A	A	A	A	B

A = "Excellent", B = "Good", C = "Moderate"

An additional study in 2008–2009 added to the understanding of water quality in the Cambodian portion of the basins.[165] The study, which was conducted during the dry season, found some harmful species of cyanobacteria and coliform, but relatively low nutrient levels, indicating that eutrophication is not a major concern. However, with increased and/or improper application of fertilisers this could change quickly. The MRC has also conducted basic biological monitoring in the basin, which can serve as an indicator for water quality and ecosystem health.[166] In the Sesan the monitoring station for this measurement is located at Phoum Pir village and measures the status of diatoms, zooplankton, littoral macroinvertebrates, and benthic macroinvertebrates.[167]

Although water quality remains acceptable in the Sesan, there are many potential pollutant sources. Data from the DONRE in Kon Tum Province noted several new factories that are permitted to discharge into the Sesan River or its tributaries. These include a sugar mill in Kon Tum which discharges up to 12,000 cubic meters of wastewater per day and the Dak Ri Peng gold mine. The report adds that many smaller firms are not registered and therefore the amount of wastewater discharged into the Sesan is likely much higher than officially reported.[168] Other pollution sources include industry and intensive agricultural operations, some mining activity, and discharge from reservoirs which may have low oxygen content and accumulated pollutants. To date these sources have not resulted in significant potential impacts to health or the environment, such as contamination from heavy metals or eutrophication. An exception is the coliform levels mentioned above (associated with

[161] MRC, 2007.
[162] ADB, 2010, p. 27.
[163] MRC, 2009.
[164] Modified from Meynell et al.2012.
[165] Tiodolf, 2009. *In:* CNMC 2011, p. 41.
[166] MRC, 2009.
[167] CNMC, 2011, p. 45.
[168] VNMC, 2010, p. 49.

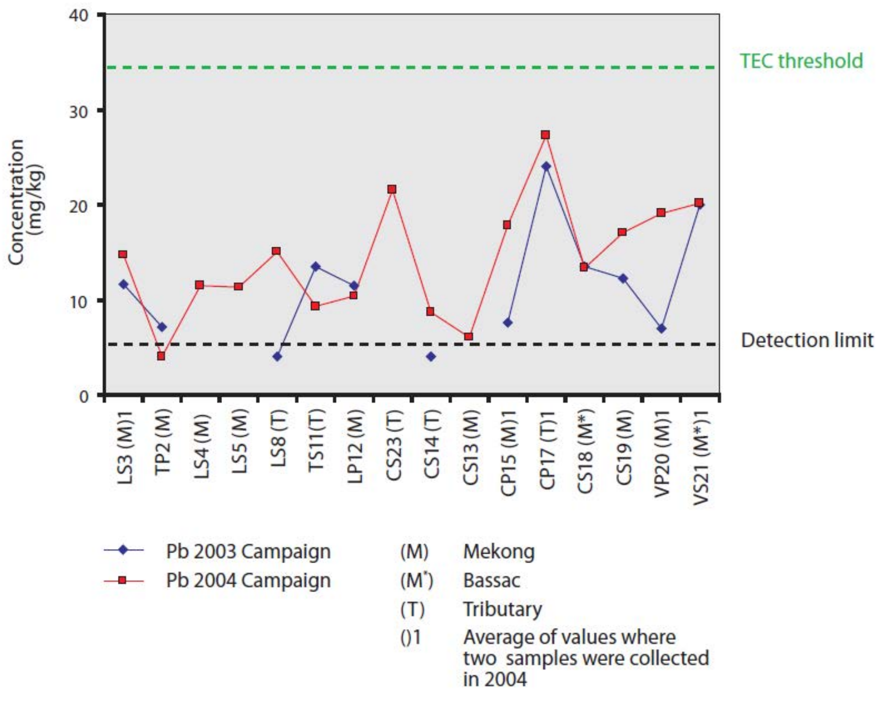
sewage).[169, 170] Nevertheless, for now water quality remains relatively high in much of the Sesan River.

In the Sre Pok the MRC has measured surface water quality at three locations: the Sre Pok River at Bridge 14 (Highway 14), downstream of the Dray H'linh hydropower plant, and downstream of the Ban Don hydrological station.[171,172] A follow up study in the Sre Pok Basin in 2011 also looked at water quality, and measurements continue to be taken at Ban Don and Pleiku in Viet Nam and at Lumphat in Cambodia. Overall the Sre Pok appears to have "good" to "impaired" water quality downstream of agricultural and urban centres, but little analytical data is available in the upstream areas. Overall the Sre Pok appears to have good quality water in its tributaries, with impaired water quality downstream of agricultural and urban centres, but little analytical data is available in upstream areas.

Heavy metals

Heavy metals are of special concern due to their ability to bioaccumulate (increase in concentration as they move up the food chain). However, they do not appear to be a major concern in most areas in the Sesan and Sre Pok Basins. In the 2004 study, concentrations of lead (Pb; from sediment samples) in the Sesan were much higher than elsewhere. However, this is still below the threshold level effect concentration (TEC). Chromium was elevated to the TEC at the sampling site in the Sre Pok. This threshold is the level below which health effects are not expected to occur.[173] As such, significant health impacts are not expected from the direct use of water. However, bioaccumulation in some plants or animals could greatly increase these concentrations. The reason for the higher concentrations at these sites is not known.

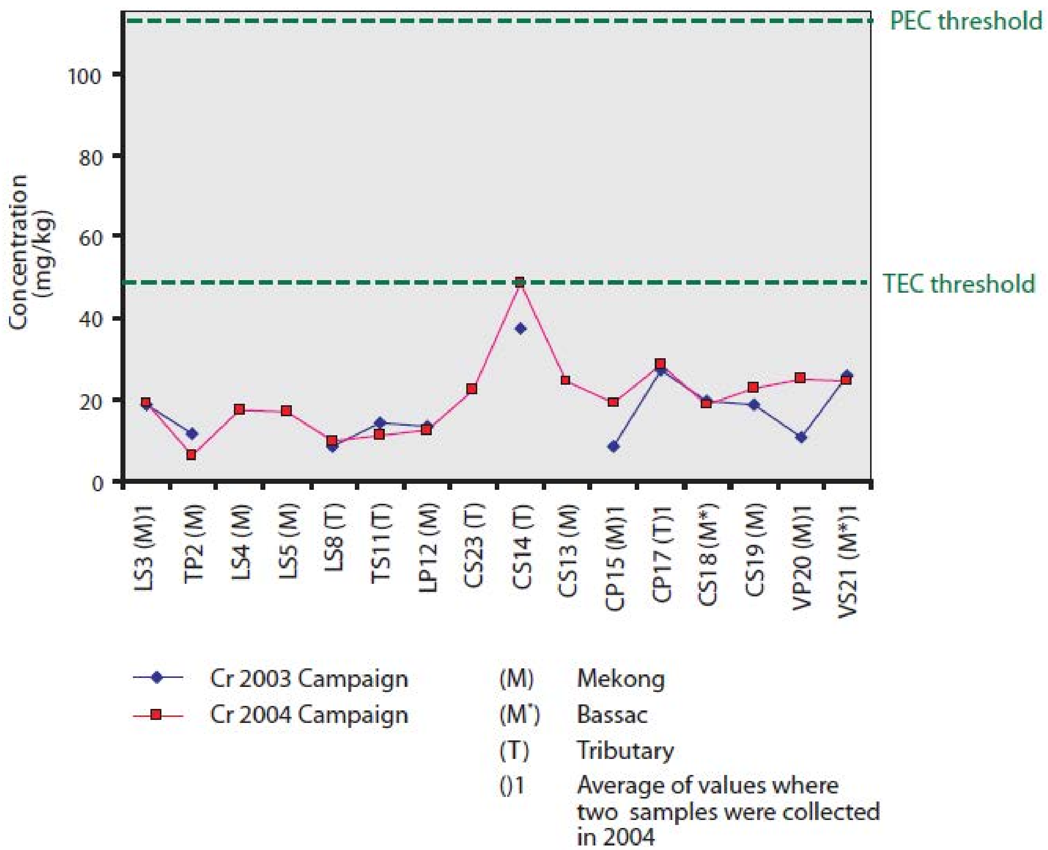
Figure 17: Lead concentrations in the Lower Mekong Basin[174]



[169] ADB, 2010.
[170] SWECO, 2006.
[171] For a detailed overview of water quality in the entire LMB and full list of parameters, see MRC technical papers 15 and 19.
[172] VNMC 2010, p. 39.
[173] Established by MacDonald, et al., 2004. *In*: MRC 2007, Tech. report No. 15.
[174] MRC 2007, Tech. Report No. 15, Figure 19, p. 41.

The Sesan Basin is represented by sampling point CS23 in the above graph. The Sre Pok Basin is represented by sampling point CS14. Although higher than most other sites in the Mekong Basin, lead concentrations in the Sesan remain below the TEC. Note: no heavy metal measurements were taken at the Sesan site in 2003.

Figure 18: Chromium concentrations in the Lower Mekong Basin[175]



The Sre Pok Basin (CS14 in above graph) had the highest measured chromium concentration. The Sesan Basin is represented by sampling point CS23. PEC in the above graph is the threshold above which health impacts are expected to occur. Note: no heavy metal measurements were taken here in 2003.

[175] MRC 2007, Tech. Report No. 15, Figure 16, p. 39.

Box 2:
Impacts on water availability and water quality

The Sesan and Sre Pok Rivers maintain relatively high integrity in terms of water availability and water quality. However, trends indicate that both are being threatened by development and natural resource extraction. Two of the most significant of these threats are changing land use and the construction of hydropower dams. If current trends continue, the basins may experience increasing dry-season water deficits and large impacts on water quality and fisheries.

Land use change
Land use in the Sesan Basin has shifted over time, moving from primarily forested watersheds to increasing agricultural areas. Although the watersheds still have extensive forest areas they are increasingly being converted for agricultural use. As forested land is cleared, the landscape cannot absorb water as efficiently. This in turn results in less water available in the dry season, increased wet season flooding, and higher sediment loads. In Viet Nam forest cover has come under pressure in the Central Highlands as the local population increases due to migration and agricultural development, especially coffee, cassava, and rubber, expands.

Hydropower construction
Hydropower dams have many effects on the Sesan River. First, they modify the flow regime, transferring some of the wet season flow to the dry season and flattening out peaks and troughs in discharge. Second, in addition to changes in seasonal flows, hydropower dams can affect daily discharge patterns. In order to generate electricity during the day, or during periods of heavy rain, dams may quickly release more water. This can result in water levels fluctuating by several metres over a short period of time. These fluctuations can impact water

5. Natural resources and development

5.1. Roads and infrastructure

Transportation is important for economic development, supporting access to markets, tourism and links to areas outside of the basin. Transportation infrastructure is limited but improving in both basins. In the Sesan major roads include National Highway 13 (Cambodia) and National Highways 14, 19, and 24 (Viet Nam). In the Sre Pok National Highway 78 travels from Stung Treng and approximately follows the watershed division between the Sesan and Sre Pok Basins. Highways 14 and 19 also pass through the Sre Pok, and Highway 14c travels north-south along the Cambodia-Viet Nam border, before turning northeast to connect to Buon Ma Thuot. From here several roads and transportation links join smaller towns

Additional minor roads run east-west through the basins. Many of the roads connecting minor towns and villages remain unpaved. During storms roads and bridges can be washed out or otherwise be damaged. Boats provide an especially important transportation method during the rainy season when roads flood and are damaged.[176] The Sesan and Sre Pok Rivers are also used for transport, but there is little established infrastructure such as docks or ports. Only small boats are reported to use the Sesan for transporting people or goods during periods of low water, when boats up to 0.3 m draught can travel throughout the area. Because there are few landing facilities these boats must often moor directly on the river

[176] CNMC, 2011, p. 81.

bank.[177] During periods when the water level is high, boats up to three tonnes and 0.7 m draught can travel along the mainstream.

5.2. Irrigated areas

The Sre Pok has the most extensive network of irrigation dams and canals, providing water for more than 40,000 ha of farmland. In Viet Nam's portion of the Sesan there may be 17,591 ha of actively irrigated land (although the design capacity is significantly higher, at 39,806 ha). There are two major reservoir and irrigation projects in the Sesan in Viet Nam: the Dak Uy and Bien Ho reservoirs. Dak Uy was built in 1975 and provides water for 1,400 ha of coffee, and an additional 300 ha of other crops. Bien Ho was built in 1979 and provides water for an additional 2,000 ha of coffee.[178] Numerous other dual-use reservoirs, such as the Yali Falls, provide irrigation water, but are also managed for electricity production. Reservoir areas in the 3S will likely increase in the future. The government of Viet Nam estimates that there are 291,000 ha of potentially irrigable land, and plans to develop all of this in the future. Less than 50,000 ha of this would be used for rice, and the rest will be dedicated to coffee, maize, and other crops. If developed, this irrigation scheme may require a total of 174 reservoirs, 490 weirs, and an additional 2,600 km of canals.[179]

In Cambodia there are only 520 ha of irrigated land, most of which was built to supplement wet season supply and not to deliver water in the dry season.[180] There are 39 irrigation projects in Cambodia's Sesan area. However, only three are currently operating, with an additional five partially operating.[181]

In Cambodia's territory in the Sre Pok there is less than 6,000 ha of irrigated land. However, this is changing and the figure may now be higher than documented. Irrigation projects are currently planned for downstream of the Sesan/Sre Pok 2 hydropower project (under construction as of 2015) and in other sub-basins throughout the Sre Pok. Although annual water demand is currently met in most areas, parts of the Sre Pok are starting to experience water shortages during the dry season.[182] To help meet this gap, extensive, often relatively small, irrigation reservoirs have been constructed in the upper Sre Pok, as well as the Sesan.[183]

The 60,000 ha of existing irrigated land in the 3S Basins may increase by an additional 270,000 ha as per current plans.[184] If this total of 330,000 ha of land is irrigated, it could potentially impact water quality and modify in-stream flow patterns. Projects are currently in the pipeline for downstream of the Sesan/Sre Pok 2 hydropower project (5,000 ha), Sesan 3 (57,000 ha), and other sub-basins throughout the basins.

5.3. Mining

In their upper reaches the 3S Basins cover part of the Kontum Massif, cutting through the soil surface and transporting minerals as they travel downstream. This geology and terrain has endowed the area with rich mineral resources which have so far not been extensively exploited. Minerals found here include gold, silver, lead, copper, and bauxite deposits. There are also known deposits of zircon and sapphire gemstones as well as some coal

[177] Someth, et al., 2013.
[178] VNMC, 2010, p. 102–104.
[179] VNMC, 2010, p. 108–109.
[180] ADB, 2010b.
[181] National Committee for Sub-National Democratic Development (NCDD) of Ratanakiri, Stung Treng.
[182] VNMC, 2010, p. 91.
[183] ADB, 2010.
[184] ADB, 2010a.

seams. Other resources extracted from the 3S Rivers include sand and gravel, which are used for construction.[185] The potential for large-scale bauxite mining is of concern. If developed in the 3S region it could have a large effect on the basins' ecological integrity and possibly require construction of more hydropower plants and transportation infrastructure.

5.4. Hydroelectric power plants

The Sesan River has seen a number of dams constructed, most notably starting with the 720 MW Yali Falls Dam in 1996. As of 2003 there were also at least 238 "hydrologic-related structures" within the basin, including around 175 weirs and 60 small to medium reservoirs.[186] Ten years later, this figure has likely increased, although there are no known updated figures for the smallest structures. Including Yali Falls, there are now eight significant hydropower dams in the basin, with one more under construction, and an additional five in various states of planning.[187] Although no large hydropower dams have yet been developed in Cambodia, the Lower Sesan/Sre Pok 2 is currently under construction and will add an additional 400 MW of capacity when completed in 2017.

[185] Ibid.
[186] VNMC, 2003.
[187] MRC, 2009.

Figure 19: Map of hydropower dams in the 3S Basins

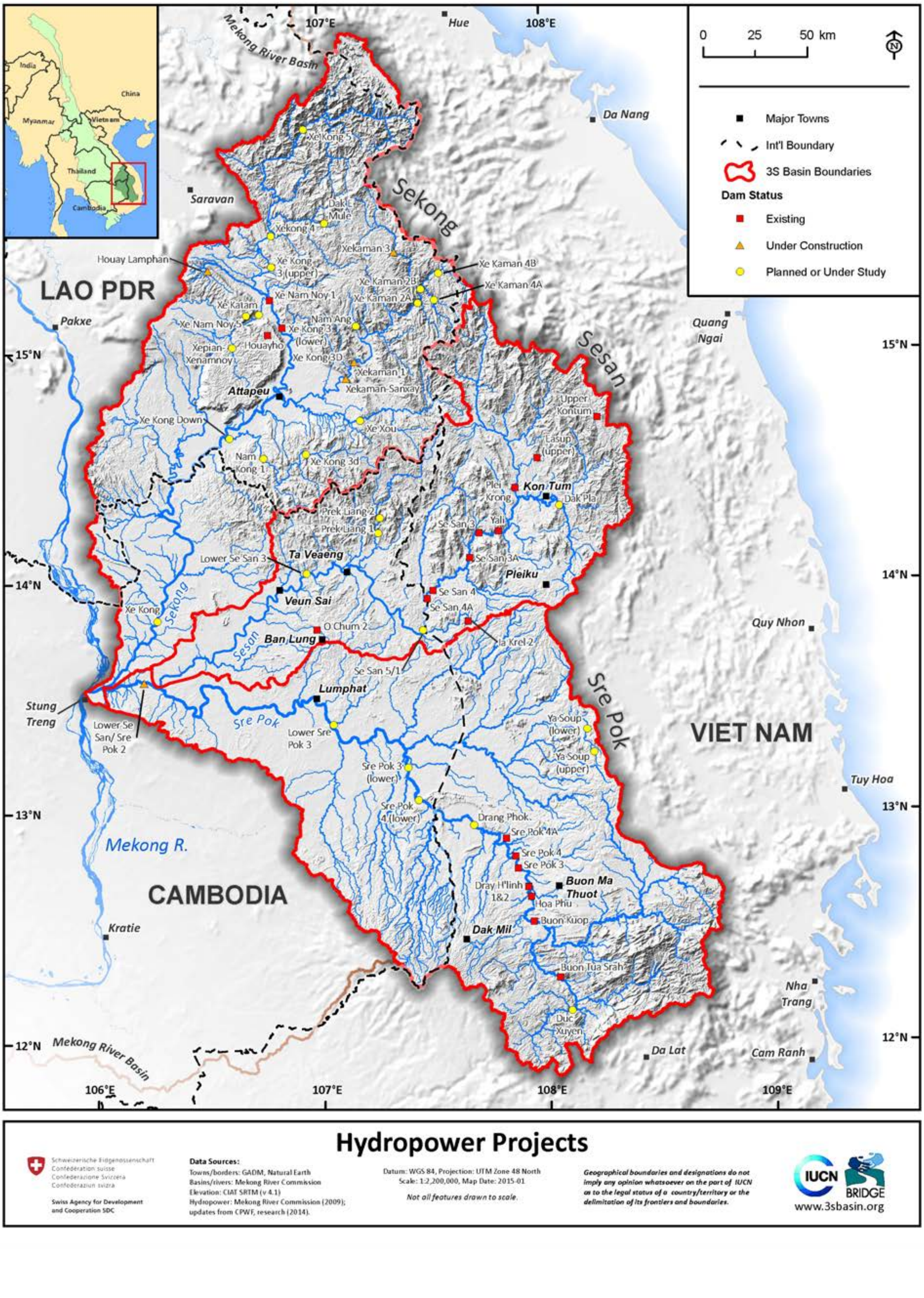


Table 19: Existing and planned dams in the Sesan Basin (data as of late 2014)[188]

Country	Dam	Status	Capacity (MW)	Year	River
Cambodia	O Chum 2	Existing	1	1992	O Chum
	Prek Liang 1	Planned / under study	64	2035	Prek Liang
	Prek Liang 2	Planned / under study	64	2035	Prek Liang
	Lower Sesan/Sre Pok 2	Under construction	400	2017	Sesan / Sre Pok
	Lower Sesan 3	Planned / under study	180	2035	Sesan
	Lower Sesan 1	Planned / under study	90	2035	Sesan
	Sekong	Planned / under study	190	2035	Sekong
Viet Nam	Upper Kontum	Existing	250	2014	Dak Bla
	Plei Krong	Existing	100	2009	Krong Poko
	Sesan 3	Existing	260	2006	Sesan
	Sesan 3A	Existing	96	2007	Sesan
	Sesan 4	Existing	360	2010	Sesan
	Yali	Existing	720	2001	Sesan
	Sesan 4A	Existing	63	2011	Sesan

The Sre Pok River also has a number of hydropower dams, many constructed quite recently. As of late 2014 there were seven hydropower dams larger than 10 MW in capacity, with one more under construction, and an additional six in various states of planning (see table, below).[189] In addition, an unknown but large number of dams for irrigation have been constructed in the Sre Pok. So far much of the development has occurred in Viet Nam, which has a higher elevation gradient than downstream Cambodia. The Lower Sesan/Sre Pok 2 Dam will be the first major dam to be developed in Cambodia's portion of the watershed, and will add an additional 400 MW when completed. The number of dams within the Sre Pok Basin places it high on an index of hydropower in the Mekong River Basin. A study by Cochrane *et al*. (2010) found that even with the current existing dams, flow patterns are altered, more than doubling the volume of dry season discharge and resulting in an 8% overall change (dry season) in flow in the mainstream Mekong at Stung Treng.

[188] Sesan/Sre Pok 2 is downstream of both the Sesan and Sre Pok watersheds. Sources (multiple): MRC, 2009; Baran, et al., 2013; CPWF Dams Database, n.d.
[189] MRC,2009.

Table 20: Existing and planned dams in the Sre Pok Basin (data as of late 2014)[190]

Country	Dam	Status	Purpose	Capacity (MW)	Year	River
Cambodia	Lower Sre Pok 3	Planned / under study	Power	330	-	Sre Pok
	Lower Sesan/Sre Pok 2	Under construction	400	2017	Sesan / Sre Pok	Sre Pok
	Lower Sre Pok 4	Planned / under study	Power	235	-	Sre Pok
Viet Nam	Buon Kuop	Existing	Power, production, irrigation, fisheries	280	2009	Sre Pok
	Buon Tua Srah	Existing	Power, irrigation, fisheries	86	2009	Krong Kno
	Drang Phok	Planned / under study	Power	26	2017	Ea Krong
	Dray Hlinh 1	Existing	Power	12	1990	Sre Pok
	Dray Hlinh 2	Existing	Power	16	2007	Sre Pok
	Duc Xuyen	Planned / under study	Irrigation, fisheries, power	49	-	Krong Kno
	Sre Pok 3	Existing	Power, fisheries	220	2009	Sre Pok
	Sre Pok 4	Existing	Power	80	2010	Sre Pok
	Sre Pok 4A	Under construction	Power	64	-	Sre Pok
	Ya Soup (lower)	Planned / under study	Unknown	*Unknown*	-	Ea Hleo
	Ya Soup (upper)	Planned / under study	Unknown	*Unknown*	-	Ea Hleo

[190] MRC, 2009; Baran, et al., 2013; CPWF Dams Database, n.d.

Further reading

For more in-depth information on the 3S Basins and related topics, please visit the web links below.

- BRIDGE/3S Basins: www.3sbasin.org
- 3S Rivers Protection Network: www.3spn.org
- Hydropower in the 3S: www.optimisingcascades.org
- Data: http://portal.mrcmekong.org
- Law and governance: www.waterlawandgovernance.org
- Law and policy: www.gwp.org/en/gwp-south-asia
- Legal database: http://faolex.fao.org

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