

Hydropower and water resource management in the Amur River basin.¹⁷¹

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The Amur River is one of the largest free-flowing rivers of the world where there are more than 120 species of fish, including anadromous salmon and the world's largest sturgeon- Kaluga. The river basin stretches from the northern boreal to the southern subtropical bio-geographic regions, therefore, presenting an exceptional variety in ecosystems. The floodplains of wetlands of the Amur valley and its tributaries serve as a crucial stopover for migratory birds and nesting site for rare species. This territory connects a few ecoregions that have a global priority in the conservations of biodiversity of the planet: wetlands of the Amur River and the Far Eastern coniferous-deciduous forests (in Russia and China), and the Daurian steppe and wetlands (Russia, China and Mongolia). The transboundary ecosystems are important for the migratory fauna, including many fish species.

Amur as development arena

The Amur is the largest international river of Eurasia. One of the most interesting features of the basin is the bordered between Russia and China. It stretches for nearly 4 thousand km, along which the sharp contrast in the population density, characteristics of land use, and cultural traditions are most noted. Throughout history, these lands were disputed over by the neighboring countries, and, combined with the remoteness of the territory, that contributed to the preservation of wild nature in the region. The border position and circumstances allowed for a greater preservation of ecosystems of the transboundary rivers like the Argun, Amur, and Ussuri. (see Annex, map "Transboundary river basins of Russia and China in the Far East").

The river water of the Amur catchment is increasingly a strategically important resource for all the countries in the region. Today, as a result of uncoordinated use of shared resources: there is a overharvesting of fish stocks; diversion of parts of river flow; unilateral construction of structures for flood control; development of hydropower plants (HPP); the discharge of untreated runoff; deforestation; etc—that are gradually reducing the productivity and resilience of the Amur ecosystem. The Amur River ceases to operate as a self-regulating resource ecosystem.

The unsatiable demand for resources in the Pacific Rim and the Russian government's desire to solve all the painfully complex socio-economic and geopolitical problems in one fell swoop bring about giant, ill-designed projects for resource extraction and energy infrastructure, like the pipeline from Siberia to the Pacific or the plan for electricity

¹⁷¹ This review originally was a chapter in **"Environmental Concerns of Russian-Chinese Transboundary Cooperation: from "Brown" Plans to a "Green" Strategy** Evgeny Simonov, Evgeny Shvarts, Lada Progunova (Eds.). Moscow – Vladivostok - Harbin: WWF, 2010. Analytical report published in Russian by WWF's Trade and Investment Programme. English edition is due in early 2012.

export to the PRC in amount of 60 billion kWh/year. The socio-economic and ecological impacts of such “massive development projects” are very complex and difficult to predict, meaning that they are accompanied by huge uncalculated risks that are not taken into account. In particular, when reviewing options for the construction of HPP in modern conditions, one should take into account all the other types of important water uses, including the maintenance of certain ecological parameters of the environment.

Russian-Chinese IWRM Scheme Case-study

As is well illustrated by the example of the joint Russian-Chinese Scheme for Integrated Water Resource Management of the Amur and Argun (SIWRM), hydropower is tightly connected to all other aspects of water use. On August 18th, 1956, an agreement was reached to perform a joint research and development project to create a Scheme for the comprehensive use of the Argun and transboundary stretches of the Amur River. As a result of almost four years of joint work of the Amur (USSR) and Heilongjiang (PRC) expeditions so-called “Project Grand Amur” was prepared by 1962. Hydro-engineering systems for generating energy and flood protection were designed for the Upper Amur. This included the Amazarsky, Dzhalinginsky, Kuznetsovsky, Suhotinsky, and Blagoveshchensky hydropower complexes. The Khinganskiy HPP in the Middle Amur was designed just for power generation and could work only after the completion of Zeyskaya, Zhelundinskaya (on Bureya) and Kuznetsovskaya water regulating reservoirs with cumulative live volume over 107 km³, accounting for 70% of the Amur river runoff. This first Scheme for the Amur practically ignored environmental impacts. The Scheme didn't even have a section on the protection of the environment. The deterioration of Sino-Russian relations in the 1960s halted further implementation of the Scheme¹⁵¹.

In the 1960s Russian scholars, had unilaterally developed a concept of “Transforming the Nature of the Amur basin,” with the following components: flow control, integrated use of river energy, improved transportation, and development of industrial fish farming in the Amur basin. The concept envisioned creation of water reservoirs with storage capacity equal to 200% of the mean annual flow volume of the Amur River, as well as active development of water transport: canals between the Lake Kizi and the Tabo Bay, Lake Khanka and the Amur Bay, etc. Although we dislike this outfashioned paradigm of a “cardinal transformation of nature”, it is necessary to note that this Concept advocated quite comprehensive approach to development, and did not just focus on use of the energy potential of rivers as the only important task¹⁵².

As soon as bilateral relationships improved in 1986 and a new agreement was signed by China and the USSR to resume interrupted work. The “Russia-China Joint Comprehensive Scheme for Water Resources Development in Transboundary Stretches

¹⁵¹ Gotvansky V.I., *Amur River basin: mastering - to preserve*. Blagoveshchensk: Zeya". 2005.

¹⁵² Nicholas V.V. and Stradomsky E. A. Editor, “*The southern part of the Far East*”, Moscow: Nauka, 1969

of the Argun and Amur Rivers” solidified this later agreement. The initial intent was to review development opportunities in hydropower, flood prevention, fisheries, and clean water supply. However, China clearly prioritized hydropower and was thus inclined to avoid or dismiss any modifications that threatened electricity outputs. Russia was eager to explore relationships between all sectors of the economy and take into account quality of water, the condition of fishery resources, and environmental issues. Nevertheless three amendments initiated by China and accepted by Russia biased the resulting scheme exclusively towards hydropower:

- The project area was demarcated to exclude the reach of the Amur River between the Songhua and Ussuri River mouths, thereby avoiding the need to explore transboundary pollution issues arising from the Songhua River;
- Flood-risk prevention was deleted from the common agenda and subsequently handled by each country independently. This opened the way for uncoordinated dyke-building along national river-banks, causing tremendous hydrological problems. Similar treatment resulted for all issues related to "water used within national territories";
- Evaluation of alternative plan -to build dams on tributaries while leaving the main channel of the Amur-Heilong River free-flowing - was deliberately deleted from the agenda, despite resentment of many Russian experts on this issue¹⁵³.

Russia and China failed to agree on many issues including dam height, exact location, reservoir volume and regime, mitigation of impact on fish stocks, and many other environmental issues. Finally Russian-Chinese commission declined to approve the full document, agreeing only on 100-page “Synopsis” (“Joint Comprehensive Scheme Synopsis” 2000) with many points of disagreement listed in the text. Half-completed document proposed up to 10 dams on the Amur River and its tributaries, while the Argun River was to be developed in a large cascade. Three dam locations on the Amur River main channel: Khingansky, Dzhalinginsky and Amarsky were agreed to be more feasible than the other and thus were called "first-stage dams" (Table 2.) Russia has continually proposed that the two countries sign an agreement on protection and use of transboundary rivers. This is cited in 2000 in documents of the Russia-China Commission as a precondition for further work on the dam proposals.

The Scheme evoked considerable public debate in Russia in the mid-1990s, scientists and public environmental NGOs actively criticized its shortcomings and submitted numerous petitions to the government. This encouraged several provincial governments and resource management agencies also to express criticism and disagreement with the Scheme. The Scheme was not recommended for environmental impact assessment (EIA) and/or subsequent governmental review in Russia and successfully shelved. Nevertheless all proposed dams on the Amur-Heilong main stem are still included in the official list of future hydropower construction sites featured on web-sites associated with the China Ministry of Water Resources (see Figure 1). Those dams are also included into

¹⁵³ Gotvansky V.I., *Amur River basin: mastering - to preserve*. Blagoveshchensk: Zeya. 2005.

become one of the routine tasks of inter-basins water transfers from Nen, Taoer, Second Songhua rivers. Even the moderate development of agriculture in the Heilongjiang Province will result in a necessity to add supplementary water from somewhere. It will be the easiest to take it from either Amur or Ussuri, but for large-scale withdrawals they will need to build reservoirs¹⁵⁶. The water can either go to farmland irrigation of the northeastern China or for diversions to the rapidly deteriorating basins of Liao, Huang He, and Huai rivers, that's why Canadian scholar, Frédéric Lasserre, had predicted the inevitable competition between China and Russia over water resources of the Amur basin¹⁵⁷.

It is quite noteworthy, that Russian-Chinese tensions first surfaced in the most water deficient reaches of the Upper Amur basin triggered by construction of complex water infrastructure, first of all a canal for the diversion of a significant portion of the Hailar(Argun) River runoff 2007-2009. The Hailar River water resources are used for quite broad spectrum of needs: the provision of coal-fired thermal power plants , supplying mining and enrichment plants, irrigation and fish farms, restoration of wetlands and tourist beaches, desalinization of Lake Dalai, providing water for municipal needs and livestock, as well as HPP¹⁵⁸. Whether two countries manage to agree on the environmental flows regime and protection of the transboundary Argun River wetland ecosystem, that they share, would have decisive influence on the future mode of competition for the water resources in the whole Amur River basin. So far, both the "historic" Sino-Russian Schemes and the modern Argun water crises show that during the periods of mutual hostility shared transboundary ecosystems were protected more consistently than in the periods of friendship and cooperation.

Existing reservoirs and HPPs in the Amur River Basin

In 2010, 100 hydroelectric power plants were active in the Amur River Basin, but only two of them in Russia (see Annex map of Existing and planned hydro-engineering structures in the Amur River basin). The installed capacity of the 2 Russian plants (on Zeya and Bureya rivers) is 3,330 MW and annual electricity production can reach up to 12 billion kilowatt hours. In terms of their flood regulating capacity and impacts on the Amur River basin ecosystems these two Russia dams might well be equivalent to all of China's hydropower facilities in the basin combined. All of the remaining reservoirs of the Russian part of the basin (about 300) have small volumes up to 10 million m³ with the purpose of water supply, irrigation, fish breeding, but not production of electricity.

Hydropower has a modest part of in the energy sector in the northeastern China and its portion declined through 2003-2009 (See Table 1). At the same time, the wind power energy has doubled annually in recent years and exceeded the numbers written into the

¹⁵⁶ C. Podolsky, E. Simonov, Y. Darman, "Where is the Amur is flowing?, WWF Russia.

¹⁵⁷ Lasserre, Frédéric. "The Amur River border : A once symbol of conflict turned into a water resource stake", Cybergéo, Revue Européenne de Géographie, n 242, pp.1-37, 2003.

¹⁵⁸ Section "Documents" website (www.dauriarivers.org).

Fiver Year Plans. In 2010, the wind farms have surpassed HPPs in both production and installed capacity ¹⁵⁹.

Table 1. Power plants in the Northeast China in 2003 and 2009 (MW)

	TPP	HPP and HAPP	Wind PP	Total
2003	35,082	5,578	123	40,832
2009	58,272	6,615**	6,272*	71,413
2009, %	81.6	9.2	8.8	100

* The power of wind energy reached over 8,000 MW by 2010. In addition to the Amur River basin, it covers Yalu, Tumen, Liao river basins(source: Xinhua News)

Source: “*On Some Strategic Questions in water and land resource allocation, environment and sustainable development in North East China.*” Summary Report. Shen Guo Fang, et al. ed. Chinese Academy of Engineering. Chinese Academy of Engineering Publishing, Beijing, 2007 (with update data from web-sites <http://hy.gzntax.gov.cn/k/2010-2/1768677.html>)

Strictly speaking, the installed capacity of HPPs in China on the Amur River basin proper is about 4,400 MW with the annual generation of 8.5 billion kWh. Out of those more than 30 existing HPPs have installed capacity of 10-400 MW and about 50-70 more have capacity less than 10 MW. Xiao Fengman, the oldest major dam in the region blocks the Second Songhua River in Jilin City in the Changbaishan foothills. Tens of other large, medium, and small HPPs block this river and its upstream tributaries. Lianhua is another large HPP on the Mudan River - a tributary of the Songhua River in the east Manchurian mountains (see Table 2.). More than 20 medium and small sized HPPs and pumped-storage hydro-accumulation power plants (HAPP) were constructed in the Heihe prefecture across from the Russia’s Amurskaya Province. At the time of their construction, all the above-mentioned facilities had power production as the main purpose even though large reservoirs were used comprehensively: for water supply, river diversion, flood control, and even to dilute pollution downstream. All the other large water reservoirs in the basin are multi-purpose and only incidentally produce energy. The vast majority of large dams constructed in the past decade fall into this category. For example, the Nierji reservoir(2006) on the Nen River, near Qiqihar City, was designed for flood control, water supply for irrigation, industrial and municipal needs of water deficient areas, maintaining a tolerable level of pollution on the river and providing ecological flows into the neighboring wetlands, etc. Nierji also has turbines with the installed capacity of 250 MW. Dadingzishan (2008) is a new dam on Songhua River 50 km downstream from Harbin. It is designed to maintain navigation depths, regulate fluctuation in the water levels in the city, and promote fish farming and agriculture, but it also has turbines of 66 MW capacity. All in all, in the Chinese part of the Amur River basin there are more than 13 thousand reservoirs and ponds; many of those with micro-hydro installed, however, their cumulative capacity yields to that of two Russian hydropower giants.

¹⁵⁹ <http://hy.gzntax.gov.cn/k/2010-2/1768677.html>

Table 2: Existing and planned, large and medium, hydropower plants in China and Russia in Amur River basin(principal examples- also see map in the Annex)

Reservoir	rivercourse	Status* (readiness)	Power	Annual runoff	Regulated Volume	Reservoir Area
In China			MW	km cu./year	Km cu.	Km square
Xiao Fengman	2nd Songhua	1	1004	13	5,350	565
Baishan	2nd Songhua	1	1500	11	4,860	
Lianhuahu	Mudan River	1	550	7	2,000	120
Jinbohu	Mudan River	1	96	3	1,000	10
Nierji	Nonni	1	250	24	5,860	507
Dadingzishan	Songhua	1	66	46	0,500	100
Yilan	Songhua	2	0	54	0,500	120
Honghuaerji	Yiminhe	2	0	1	0,200	50
Hadashan	2nd Songhua	3	90	16	3,350	240
Zhaluomude	Hailar	3	0	2	0,300	100
In Russia						
Bureyskaya	Bureya	1	2000	28	10,700	740
Zeyskaya	Zeya	1	1330	24	32,100	2419
Lower-Bureskaya	Bureya	2	321	29	0,070	153
Lower-Niman (Ugalskoe 1)	Niman	3	450	7	8,300	371
Rusynskaya	Selemdzha	3	550	7	4,460	220
Gramatuhinskaya	Zeya	3	300	32	2,300	62
Dalnerechenskaya	Bolshaya Ussurka	4	660	7	4,300	327
Ust Niman	Bureya	4	400	12	8,300	371
Giluy	Gilyuy	4	380	6	3,250	209
Khorsky	Khor	4	133	3	0,500	220
Ikindinskyy	Selemdzha	4	140	9	4,460	440
Shilkinsky (Trans- Sibiskaya)	Shilka	3	600- 1300	15	10	470
Transboundary Amur						
Khingansky- Taipinggou	Amur	3	1800	151	1,140	166
Dzhalindinsky -Lianing	Amur	4	1000	35	1,800	447
Amazarsky-Mohe	Amur	4	2000	28	18,700	660

* The status of HPPs in 2010: 1 – operational; 2 - being constructed; 3 - in current development plans, adopted after 2000; 4 – designed before the year 2000 (conceptual).

Source: Amur Information Center Database

Hydropower Potential and Planning for its Development

Russia

A myth of “endless” untapped hydropower resources of Eastern Russia is nowadays very popular but poorly supported by reality. In official documents of RusHydro and governmental agencies, it is stated that only 3% of hydropower potential of the Far East rivers is being used. This statement is based on ancient piece of research conducted in the USSR in mid 1960s¹⁶⁰. Today, leading Russian experts are urging for a re- evaluation of economically-feasible hydropower potential of Russia. They refer to multiple factors that necessitate such review:

- the rising cost of constructing hydroengineering structures;
- the strengthening of environmental restrictions and regulations;
- substantial increase in cost of environmental protection, in part, for fish protection and fish passing facilities, clearing reservoir beds, maintaining water quality, etc
- stricter requirements for the living conditions of the resettled human population ;
- the emergence of new opportunities for use of natural resources that would have been lost due to reservoir inundation;
- competitive circumstances related to the changing economic conditions and systems of market evaluation, that are used in the analysis of effectiveness of hydroelectric projects¹⁶¹

As a result the economically feasible hydropower potential of the Russian side of the Amur basin, which in 1967 was evaluated at 60 billion kWh/year, today with the new calculation decreases to approximately 30 billion kWh/year. From those power generation at the existing and presently constructed HPPs amounts to 14 billion kWh/year. Thus hydropower potential of the Russian side of the Amur basin, calculated just from the perspective of economic and legal requirements (without consideration of the ecological limitations) has already been utilized by 50%. As a result of such new calculation done for three large basins of the Far East (Lena, Amur, and Kolyma) presently economically feasible potential decreased from 317 billion kWh/year (expected in 1967) to only 85 billion kWh/year. From those 24 billion kWh/year (28%) is already in use. This way, the rate of present use of the economically accessible hydro potential of the Far East is at least 10 times higher than the official statement of RusHydro and the Ministry of Energy, even before ecological and geopolitical limitations are accounted for¹⁶².

¹⁶⁰ *Energy Resources of the USSR. Hydropower* (ed. A. Voznesensky.) USSR Academy of Sciences, 1967.

¹⁶¹ Asarin A., Danilov-Danilyan V.. We have been generous in the assessment. "World Energy", May 2007, № 5 (41).

¹⁶² Ibid.

Corporate, institutional, national, and regional plans and strategies issued in last 5 years are promising to start in next 20 years 15 hydropower construction projects in the Amur River basin (as well as another 10 projects in adjacent basins):

Amur Complex: Shilkinskaya (Trans-sibirskaya) HPP on the Shilka River; Gramatuhinskaya (Lower Zeya) HPP on the Zeya River; Rusinovskaya and three more hydropower plants on the Selemdzha River; Lower Bureya, Nizhnenimanskaya and Ust-Nimanskaya HPPs in the Bureya River basin ; and for Ussuri River Basin there is the Dalnerechensky cascade on the Bolshaya Ussurka River and Sukpaysky' cascade of HPPs on Khor and Sukpai rivers.

Transbaikal complex (Lena Basin): Mokskaya HPP and Ivanovski counter-regulator on the Vitim river, as well as Karalonski, Telmamski, Amalykski, and Bodaibo HPPs.

Southern-Yakutsk complex (Lena basin): Kankunsky, Nizhnetimptonsky, Aldansky, and Uchursky HPPs.

Tidal power: Tugursky TPP in Tugursky Gulf of the Sea of Okhotsk in the Khabarovsk Province.

“Competitive advantage” of almost all those HPPs above stressed by their proponents is that “they already have complete project documentation developed” i.e. these are plants with 20-40 year old obsolete designs that compete now for money of “federal investment funds”.

In addition, according to the draft “Energy Strategy of the Far East” (2008) proposed gradual increase in the electricity exports from facilities that find no demand in the domestic market of Eastern Siberia and the Far East. It is planned to use for export old plants (i.e. Zeysky HPP) as well as develop new generating capacity (i.e. Lower Bureya HPP).

In 2010-2011 to expedite electricity exports to China the YES-Energo joint venture was founded by Chinese Yangtze Power (subordinate to Three Gorges Co.) and Cyprus EurosibEnergo (belongs to Russian billionaire Deripaska, controls HPPs in Enisey River basin). In the first stage of the venture, YES Energo will examine two hydropower and one thermal power project in Eastern Siberia with a total installed capacity of over 3 GWt, then additional 7 GWt will be considered in the second stage. One of the two proposed dams is Trans-Sibirskaya HPP on lower Shilka River with installed capacity from 400 - to 900 MW. The Onon-Shilka watercourse is the primary source of the Amur flowing from Mongolia into Russia and thus upper part of the main stem of Amur River System. An assessment of such hydropower project in the same stretch of Shilka River done by Chita research institute of Academy of Science in 1990 came to conclusion that it is environmentally and socially unacceptable due to high negative impact on fish, water quality, regional biodiversity and living environment of local people. This hydro in 2010 was not in the HPP construction plan recently approved by the State and was not a part of any regional development strategy. Nevertheless hydropower companies shamelessly and aggressively promote expedited construction of such HPP projects.

China

A consistent evaluation of the general economic hydropower potential of the Amur Basin is made difficult by division of responsibility (and statistics) for large and medium/small HPPs between China's different government departments . It is economically feasible to

use 233 sites on rivers (with potential of more than 10 MW each), where there can be installed capacity of 9300 MW with annual generation of 19,630 billion kWh. A potential for construction for pumped-storage hydroelectricity in the same area is about 30,000 MW¹⁶³. Large hydropower has a small role in the “Revival of the Northeast” Program and the 12th Five Year Plan (until 2020) with only 500-600 MW of newly installed HPP capacity in the Amur basin¹⁶⁴. This is not only because many sites suitable for large HPPs are already engaged, but also because of the increased socio-economic limitations imposed on the river management. On the other hand, in the same period, Heihe Prefecture plans to add 160 MW installed capacity in 11 small HPPs not accounted in national statistics and construction of small HPPs will continue in all other mountainous areas. However, in most places, water reservoirs will be built, not so much driven by demand for electricity, but to satisfy other societal needs (municipal supply, irrigation, etc), even though, wherever possible, a small power generator is mounted into the dam.

With a rapid growth of energy sector in Northeast China, the share of hydropower naturally decreases (see table 1). This is due to many factors, including new requirements for environmental flows on rivers. The only possibility of a large-scale development of the hydropower industry is the construction of HPPs in the main channel of the Amur River, which will also help to solve the problem of diverting Amur waters inside China. That is why the political pressure from China on Russia to agree on damming the Amur River will not decrease in the foreseeable future.

Risks and Environmental Impacts of Hydropower on a River Basin Scale

In the PRC, where there are a lot of factors at work—like the massive withdrawals of water for various needs, pollution, and embankment construction—it is more difficult to single out and assess the role of HPPs in overall anthropogenic pressure. The ecological impacts of hydropower plants are more evident in Russia on the Zeya and Bureya tributaries of the Amur, where other human impacts are comparatively small.

When assessing the cumulative effects of several HPPs on the ecological condition of the basin, first and foremost we consider the following broad impact factors:

1. Alteration of flow regime downstream of dams and through that effects on the three dimensional interaction of the river and valley
2. Catastrophic transformation of riverine habitats in the region and their replacement by water reservoirs ;
3. Fragmentation of river network, including disruption of migration routes of species and material transport

¹⁶³ “On Some Strategic Questions In Water And Land Resource Allocation, *Environment And Sustainable Development In North East China.*” Summary Report. Shen Guo Fang, *et al. ed.* Chinese Academy of Engineering. Chinese Academy of Engineering Publishing, Beijing, 2007, <http://hy.gzntax.gov.cn/k/2010-2/1768677.html>

¹⁶⁴ http://www.xinhuanet.com/chinanews/2008-08/22/content_14191988.htm

In assessing the impact of individual HPP projects, experts usually also evaluate many local impact factors (eg, seismic risks, reservoir bank erosion, the destruction of terrestrial ecosystems and species habitats, change in local climate, displacement of people, etc). However, important local factors usually do not determine the cumulative effect of HPPs on the whole river basin. Therefore we use them only in more detailed analysis, while 3 main factors listed above are essential part of our strategic assessment of development plans.

FLOW ALTERATION BELOW DAMS

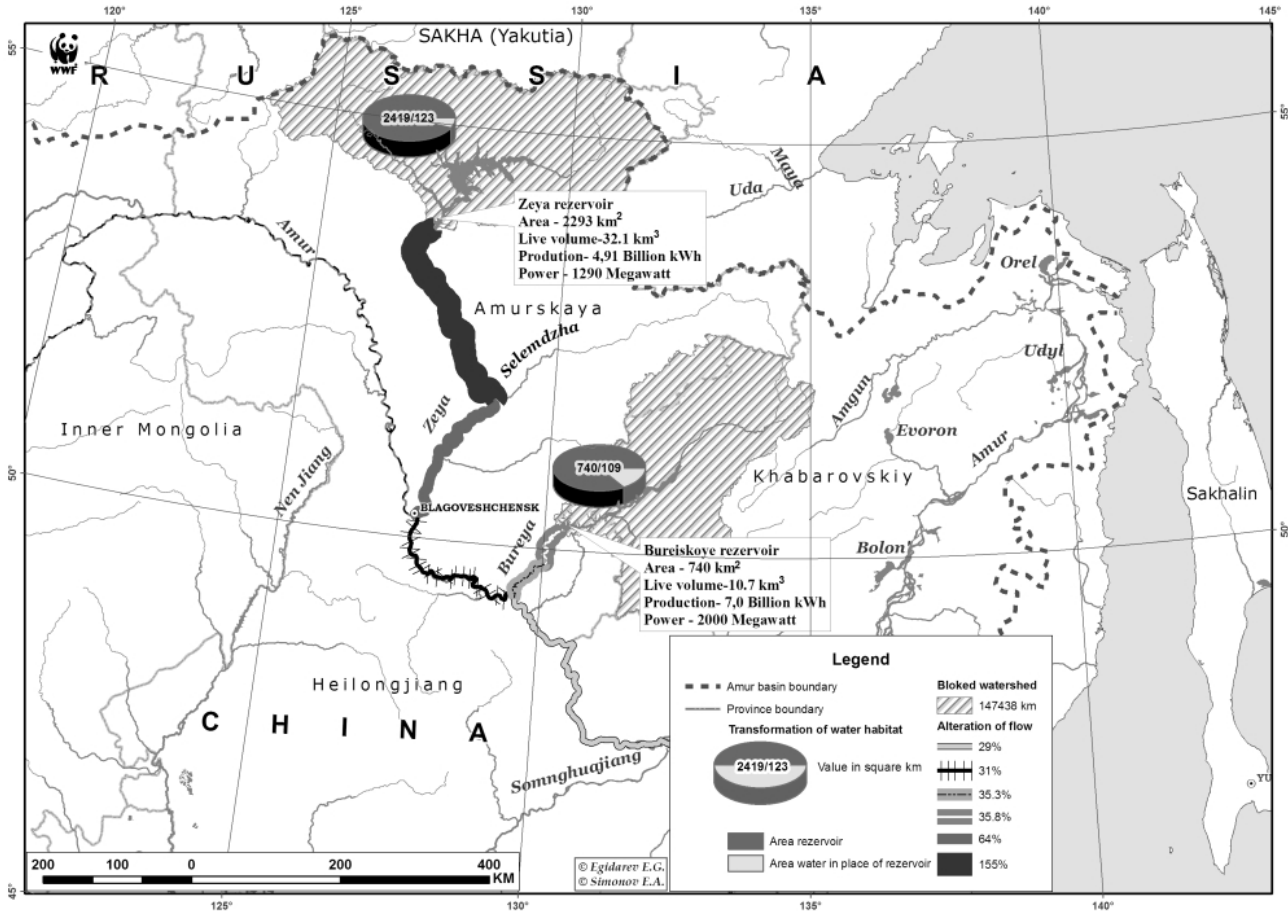
The biota and ecosystems of the rivers in the Amur catchment are dependant on the floods that are cutoff by HPPs. The mere regulation of the Zeya has caused the decrease of the water level during large floods on the Middle Amur by 2.8 m and by 1.7 m in Khabarovsk. The flow regime of Zeya and Bureya has changed significantly, which has resulted in the actual loss of natural floodplain ecosystems on both rivers. But the impact of HPPs has also spread downstream onto the main channel of the Amur River., For example in Amur valley near Khingansky nature reserve, floodplain areas that used to be flooded every 20 years, from now on will be inundated not more than once every 100 years; and some important areas that received only highest floods have become completely independent from flood influence. This causes decline in typical floodplain communities, habitats of cranes and storks, refugia for other important species.¹⁶⁵. Populations of *phytofile* fish species in the lower section of the Middle Amur, the upper section of the Lower Amur, and the Lower Zeya River have been greatly reduced and species composition has changed¹⁶⁶. The degradation processes of the floodplain system of the Amur River under the cumulative influence of Zeya's and Bureya's hydropower plants are further exacerbated below the mouth of the Songhua River, where water regime has undergone additional anthropogenic changes due to construction of hydro-engineering structures on the territory of the PRC. Hydrologists see distinctive changes in the water levels and fluctuations of the runoff due to the influence of HPPs all the way down to the Amur River mouth¹⁶⁷. The reservoirs drastically reduce sediment flow below the dam, and due to the lack of sediment the erosion process is activated. , This is particularly evident on the Zeya River which as result become impassable for most ships.

Fig 2. Parameters of Environmental Impacts by Zeysky and Bureisky HPP.

¹⁶⁵ Podolsky, S., Simonov, E., Darman, Yu., "Where does the Amur flow?", World Wildlife Fund, 2007.

¹⁶⁶ Kotsyuk, D.V., "Ichthyofauna Structure And Dynamics Of The Stock Of basic Food Fish Zeya Reservoir / Readings In Memory." Konovalova S. M., Vladivostok: TINRO, 2008; Kotsyuk D.V., Report to WWF on the justification of environmental releases, 2008.

¹⁶⁷ "Scientific rationale for the project of socio-environmental monitoring and database of influence on the Bureya hydropower." Report IWEP, 2002.



The greater is river flow alteration capacity by reservoirs—the greater are changes in hydrology and in ecosystems downstream. This could be expressed as ratio between live volume of upstream reservoirs and mean annual flow at a given river section. For Middle Zeya, the degree of flow alteration is 155-100% (meaning that the mean annual flow volume is less or equal to live volume of reservoirs). for Lower Bureya flow alteration is 35%; for Lower Zeya - 64%; and for the Amur downstream from Blagoveshchensk it is 29% (see Fig 1). In China, Second Songhua and Songhua rivers have a similar degree of flow regulation. Unfortunately, economists analyzing water management such flow alteration capacity of reservoirs interpret this only as an important benefit that reduced the flood damage with no consideration to its environmental impacts.

ECOSYSTEM TRANSFORMATION BY RESERVOIRS

Any reservoir is an anthropogenic feature created in place of the most important socio-ecological landscapes—river valleys. We may assume that the larger the surface of the water reservoirs and the greater is their share in all water surface of the river system, the stronger they transform aquatic and terrestrial ecosystems. The Bureya and Zeya reservoirs are enormous: together they occupy 3,160 km², which equals roughly 45% of the total water surface in the Middle Amur Freshwater Ecoregion in Russia. In China, all reservoirs of the HPPs of the basin occupy only half of that area. The Zeya and Bureya reservoirs have low quality water, in part due to inundation of massive volumes of vegetation, soil, and peat. Before Zeya dam construction, the composition of fish fauna of the Upper Zeya Basin in 1970 included 38 species, by 2007 the fish fauna of the Zeya

Reservoir was reduced to 26 species¹⁶⁸. Fish stocks of the Zeya reservoir have been in seriously depressed state for many years. Reservoir also serve as places for initial introduction of exotic species that then may spread in the whole river basin.

FRAGMENTATION OF RIVER NETWORK

Dams that block/isolate parts of the river system from each other and thus contribute to fragmentation of a river basin. As a result, the migration of aquatic organisms is stopped, and there is a delay in runoff of biogenic elements¹⁶⁹. For example, above the Zeya and Bureya dam the sturgeon, Kaluga, salmon, lamprey and other migratory species have already disappeared. A simple measure of the fragmentation of the river basin is percentage of the basin area, which is cutoff from the sea by dams. Taken together, the Zeya and Bureya dams block 8-9% of the Amur catchment area, while all of the existing dams in China block additional 22-23%. This means that nearly one-third of Amur River system has been already isolated from the sea and no longer can sustain migratory species, e.g. diadromous fish.

Major negative aspect of proposed Trans-Sibirsky dam result from its location in the lower reaches of Shilka, which would isolate 200000 square kilometers or another 10% of Amur River basin by development of a single project. When compared with 60 other existing and proposed hydropower projects in Amur Basin Shilka HPP shows greater potential environmental and social impact both in absolute figures and per unit production than the majority of other dams. Only Sino Russian hydropower plants proposed on the main stem of Amur River proper look more harmful than this project.

If we agree with the necessity to preserve the self-regulating resilient Amur ecosystem and the role of this river as a transboundary ecological buffer, we have to conclude that impacts of hydropower on the Zeya, Bureya, and even on the segment of Amur (from the mouth of the Zeya to the Khingan Gorge), possibly have already exceeded the thresholds of "limits of allowable change". First of all it is manifested in disruption of sedimentation process in river channel habitats, negative impacts on fish and reducing are of floodplain wetland ecosystems.

Hydropower Development Scenarios and Water Resources and Opportunities for Optimization

In different countries of transboundary Amur River basin people have different perceptions on the risks and perspectives of hydro engineering. But basin-wide

¹⁶⁸ Kotsyuk, D.V., *"Ichthyofauna Structure And Dynamics Of The Stock Of basic Food Fish Zeya Reservoir / Readings In Memory."* Konovalova S. M., Vladivostok: TINRO, 2008

¹⁶⁹ Nilsson C., Reidy C. A., Dynesius M. & Revenga C. *"Fragmentation And Flow Regulation Of The World's Large River Systems"*, 2005, Science 308: 405–408.

environmental impacts of hydro-engineering on the same ecological and hydrological system of Amur, should not be measured by a different national yardsticks.

A remarkable Far-eastern scientist, Vladimir Sapaev, who recently passed away, in his last article “Amur Flow Regulation—is Optimization Possible?”, left to us a challenge: “*The most important objective should be to protect the Amur River, its floodplain containing main biological resources and ecological services as well as natural support-base for the local communities of the southern Far East. The methodology for the evaluation of the socio-ecological impacts and criteria for future HPP construction should be developed based on this main concern*”¹⁷⁰. Keeping that in mind we now examine several very broad conceptual development scenarios.

Scenario #1: Implementation Sino Russian IWRM Scheme for Amur and Argun

As already described above, the Russian-Chinese IWRM Scheme suggested massive hydropower development on the main channel, and also on yet undammed tributaries. The Chinese side and a number of Russian institutions are still actively lobbying this option. In 2007, “The Chinese Industry Newspaper” expressed the readiness of the PRC government to fully fund and build a Khingansky-Taipinggou HPP; with all of its energy to be used in China.¹⁷¹ In Sept 2011 at the Baikal Economic Forum the vice-head of the Three Gorges Co. Chen Guoqing again stressed that **hydropower projects on the border river (i.e. Amur River)** need the guidance and co-ordinations from the energy and water resource departments from both countries¹⁷²...

The important incentives for implementation of this scenario are:

- a better long-term control over water management and water supply for the national economy of the PRC;
- the development of inexpensive (even by Chinese standards) electricity (assuming that the project does not pay for ecological functions disrupted by it);
- the possibility to increase the flow of Chinese workforce into Russia in the prestigious construction industry of HPPs and a large new market for the Chinese hydro-development business (besides a full Scheme containing 6-9 dams in the transboundary rivercourses, there are 70 more potential large dam sites on Amur tributaries in Russia);
- influx of Chinese investments into border areas, as well as construction and management costs being covered by the Chinese side, are attractive factors for some of the Russian executives.

Many experts evaluate this scenario as bad (even catastrophic) for its impact on the environment of the Amur and the development of inequitable socio-economic cooperation in the border areas. Instead of resolving already existing acute problems of

¹⁷⁰ Sapaev V. M., “*Regulation of the Amur River. Is it possible to optimize the environmental conditions?*” Science & Nature FE, 2006.

¹⁷¹ China Industrial Newspaper, 3.03.2007

(<http://hk.sznews.com/2007035/ca2598712.htm>,

¹⁷² <http://www.dauriarivers.org/appeals/hydropower-for-the-sino-russian-friendship/>).

integrated river basin management and environment safety in the Amur basin, the Scheme proposed to create new, much more serious problems and then try to mitigate their consequences. Several papers, including “Where is the Amur Flowing” have been dedicated to the assessment of IWRM Scheme¹⁷². The implementation of the Scheme, even partial, will result in flow alteration of the Upper Amur to 60% (presently less than 1%); Middle Amur downstream from Blagoveschensk up to 45%; and Amur at Khabarovsk up to 30%. That means that the great River will practically be deprived of all natural floodplain ecosystems. Reservoirs in the Amur valley will occupy 130 thousand hectares, and total fragmentation of the river basin will reach 73% (from present 30%)..

With just Khingansky-Taipinggou HPP in place, sediment flow will decrease by 5 million ton. Without receiving a compensating quantity of sediment, the Lower-Amur lowlands, which presently submerge with the speed of 10 cm per century, will be subject to increased waterlogging¹⁷³.

If the Amur were regulated according to the Scheme saving its fish stocks would be impossible. Even the Scheme documents forecast that the decrease in the annual flooding due to cumulative action of reservoirs on Zeya, Bureya and Amur rivers will lead to a fundamental deterioration in fish habitats all the way down to the mouth of the ocean. The expected damage (by 2030) to the fisheries of Russian Amur was estimated at 9,185 tons, including 7,360 tons of salmon and 600 tons of sturgeon. Even the full-scale fish restocking of the water reservoirs cannot compensate for more than 10% of the losses¹⁷⁴. Amur River runoff also brings important nourishment to rich fisheries in the Sea of Okhotsk and impacts of dams on disruptions in this economically important food chain have not been estimated.

Scenario #2: "Opportunistic" hydropower development in national parts of the basin

The situation in China and Russia is radically different, despite similar calculations of “underutilized” energy potential. Practically all of the dam projects in the PRC are multi-purpose endeavours with a modest hydropower component. As a matter of fact, only one of the known modern hydro-engineering schemes - development of water resources in the Hailaer River Basin is associated with serious transboundary implications for transboundary Argun River¹⁷⁵.

¹⁷² Podolsky, S., Simonov, E., Darman, Yu., “Where does the Amur flow?”, World Wildlife Fund, 2007..

¹⁷³ Mahinov A.N., “Modern relief, in the conditions of an alluvial accumulation.” Vladivostok, Dal'nauka, 2006.

¹⁷⁴ Scheme For Integrated Water Resource Management sections of the border rivers Argun and Amur. M.: Sovintervod, including “Fishing industry”, 1993.

¹⁷⁵ The section "Documents" of the website www.arguncrisis.ru.

Further development of hydropower on tributaries inside China cannot significantly increase overall impact on the Amur River basin ecosystem as a whole. Neither the degree of flow alteration, nor the degree of basin fragmentation, nor the surface area of the reservoirs can undergo radical increase in the PRC, for there is already no room for it. Not hydropower development, but the growing water consumption, especially in agriculture and the resulting non-point pollution with fertilizers and pesticides are the actively growing impacts on Amur catchment from China side. In recent years in Northeast China the scale of negative impact on waterbodies from new coal-based thermal power plants is quite compatible with that of HPPs—due to massive disruption of natural river ecosystems by associated water infrastructure (Table 1).

In Russia, where there are still plenty of un-dammed tributaries with plenty of water and natural resources, it is a different story. Most of 70 potential dam sites are quite suitable for the creation of large HPPs, and while this energy is not needed by Russian Far East, it is always in demand among neighbors. Construction of only 15 new HPPs, proposed in the recent Russian programs (Table 2), would lead to flow alteration in the Upper Amur River up to 20%; Middle Amur below the Blagoveschensk up to 60%; and the Amur below Khabarovsk - up to 40%. 270 thousand hectares of reservoirs will appear on the tributaries and the degree of fragmentation of the basin will reach 43%. Even without blocking the main channel, the Russian side can deprive Amur of its natural floodplain ecosystems, at the least to the degree that can be now observed near the mouth of the Zeya River. In this scenario, from all relatively large tributaries, only the Bikin, Tunguska and Amgun rivers will escape direct negative impacts. Although, those rivers are undeniably remarkable natural pearls; nevertheless, they would be but a tiny remnant of the former diverse Amur River basin ecosystem.

HPP on Shilka River aggressively promoted by Sino-Russian EN+YPC consortium is the most vivid example of threats presented by such development. Preliminary assessment done in 2011 by WWF Russia and Rivers without Boundaries Coalition shows that besides abovementioned consequences, the new dam would also likely have negative impacts on IUCN-listed Kaluga sturgeon, many local salmonid fish, as well as on fisheries tourism in upstream Mongolia, which is dependent on fish stock replenishment from the Shilka and Upper Amur. 450 kilometer long reservoir will occupy roughly a half of Shilka River proper destroying most livable river valley in this boreal zone. It will block important migration corridor between Amur River proper and northern Dauria upstream, exterminate floodplain communities unique for Dauria and Upper Amur, drown many important historical sites and artifacts. Besides, Trans-Sibirsky Dam on Shilka is adjacent to several HPP construction sites proposed on the main stem of Upper Amur and its construction would facilitate further development of hydropower plants downstream.

Thus active Russian-Chinese cooperation on the indiscriminate construction of HPPs on some tributaries can easily escalate into the development of the main channel (combination of scenario 1 and 2), which will have most detrimental impact on the natural of the Amur River Ecosystem, practically leaving it to history..

Scenario #3: "Selective " Hydro Engineering

To make sound decisions about hydropower development and limitations to be imposed, and therefore to preempt environmental and social tensions, we should:

- design a system for the evaluation and limitation of environmental impacts of hydroengineering projects in the region;
- identify possible zones of influence for each dam and dam cascades;
- rank all potential dams and their combinations in the basin (development scenarios) according to the degree of possible environmental impact;
- analyze consequences cascade development of HPPs, the extent of its environmental and economic feasibility for the Amur River basin and compare it with other alternatives of HPP placement¹⁷⁶.

For each freshwater of 7 freshwater eco-regions of the Amur River basin, in each of the larger sub-basins scientifically valid norms of acceptable level of flow alteration and fragmentation should be legally established that will guide restriction of the location and size of water reservoirs.

“No go areas” should be also delineated to conserve part of the basin in its wild natural state. Russian top experts Asarin and Danilyan note that some legal environmental requirements can mean a de facto ban on the construction of hydropower facilities, e.g. Law on Protected Areas¹⁷⁷. Such a ban, obviously, should also be imposed on the main channels of border rivers, natural heritage sites, major salmon-spawning rivers, etc. Sustainable development in general requires a polarized scheme of territorial expansion of human activities, which implies that significant sections of each of the major sub-basins should left in natural state and thus be exempt from large-scale hydro-engineering. To account for cumulative integral effect of already functioning and planned HPPs on flow regime and other parameters of the environment, several long-term scenarios with different new HPP locations should be developed in detail and assessed so that it would be possible to choose the least environmentally dangerous scenario of basin-wide hydropower development.

A more effective approach could have been realized during the preparation of Schemes for Integrated Water Protection and Use (Russian Water Service is the responsible institution) and analogous schemes in the PRC. Ideally, a transboundary Russian-Chinese-Mongolian basin-wide scheme is required; however, disappointing results of past Sino Russian cooperation on such schemes preclude us from recommending to start such cooperative effort tomorrow.

Scenario #4: “Fix the River First!”

Nowadays, any new comprehensive development plan has to be based on the priority of environmental safety and the restoration of the ecosystem of the Amur, and not the accelerated development of just one of the branches of economy (hydropower).

¹⁷⁶ Sapaev V. M., *“Regulation of the Amur River. Is it possible to optimize the environmental conditions?”* Science & Nature FE, 2006.

¹⁷⁷ Asarin A., Danilov-Danilyan V. We have been generous in the assessment. *“World Energy”*, May 2007, № 5 (41).

Transboundary Amur requires use of the best environmental standards of planning and operation for infrastructure facilities in context of integrated use and protection of natural resources.

First, for the already existing HPPs environmental flow requirements have to be established for each reservoir based on optimal regime of water supply to floodplains and the economic requirements of HPPs¹⁷⁸. Ichthyologists consider that in wet years, concerted discharge from the reservoirs, simultaneous with lateral natural inflow, could increase water levels in the Lower Zeya, Middle, and Lower Amur to the levels sufficient for the flooding of the lower parts of floodplains and for the passage of phytophilous fish species to spawning areas¹⁷⁹. Some environmental flow requirements for the Amur were calculated even during the unsuccessful Sino Russian IWRM Scheme in the 1990s. Since 2007 Russia has approved regulatory framework for calculating “limits of acceptable impact to the water bodies”, including environmental flow requirements.

Environmental flow release, ensuring migratory fish passage, and maintenance of natural water temperatures are all common ecological questions in designing and operating of dams which are now routinely addressed in most countries. In the Chinese section of the Amur River Basin, the ecological water requirements are calculated and provided for an increasing number of wetlands, and nearly a quarter of the live volume of the Nierji reservoir is designated for environmental flow releases¹⁸⁰.

In Russia, these issues are most important precisely in relation to HPPs and despite the requirements of the law and regulations problems are still not being solved. First, these problems have to be solved for Zeya’s and Bureya’s HPPs, and then the question of better environmental standards for design for new HPPs in should be addressed.

Conclusion

Management of water reservoirs requires coordination between nations of the transboundary basin, but not on the basis of the outdated and dangerous “Sino-Russian IWRM Scheme of transboundary parts of Argun and Amur rivers”, but on the basis of convergence of modern thinking on the joint environmental safety and resource security. The urgent need for a joint definition of norms for the environmental flow on the transboundary watercourses became particularly evident, in conjunction to water engineering in the Argun(Hailaer) river basin. But it is equally evident in the cases of cumulative impact of the Zeya, Bureya, and Songhua flow regime on the transboundary

¹⁷⁸ Sapaev V. M., “Regulation of the Amur River. Is it possible to optimize the environmental conditions?” Science & Nature FE, 2006.

¹⁷⁹ Kotsyuk D.V., Report to WWF on the justification of environmental flow releases, 2008.

¹⁸⁰ «On Some Strategic Questions In Water And Land Resource Allocation, Environment And Sustainable Development In North East China.” Summary Report., Shen Guo Fang, et al. ed. Chinese Academy of Engineering. Chinese Academy of Engineering Publishing, Beijing, 2007.

channel of the Amur river. Given that the provision of environmental flow for protected floodplain wetlands has already become management practice in the PRC, there is hope for quick development of a common language on these issues. However such optimism is quite limited looking how resistant China is to managing transboundary rivers in an integrated approach in Mekong or Salween river basins, and that such resistance is against the best available science and the sustainability of the water resource.

Our main recommendation is that Scenario #4 — i.e. implementation of acceptable environmental standards on the existing HPPs—is a mandatory first step, and only after it is completed, can a decision be made on the feasibility of the Scenario #3 - i.e. responsible continuation of hydropower development in the Amur basin. Since environmental risks from new HPPs are evident, while the economic need for their construction is questionable—and these doubts are only becoming stronger with time. In any case, energy-thirsty neighbors of Russia, for whom we are willing to block rivers, at home already tend to rely on wind and other cleaner technologies.

Near future will bring many more technological breakthroughs in energy and water use. Therefore, using natural capital in responsible and sustainable manner without haste, we can save a significant portion of our resource potential for more efficient use with use of new technologies.

Maps (prepared by Evgeny Egidarev WWF-Amur Branch and Pacific Institute of Geography

Annex 1. Map Transboundary River basins of Russia and China in the Far East

Annex 2. Map of existing and planned hydro-engineering structures in the Amur River basin.

